A. Clifford

MODERN ORGAN BUILDING

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Practical Explanation and Description of Organ Construction with especial regard to Pneumatic Action and Chapters on Tuning, Voicing, etc.

BY

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(ORGAN BUILDERS)

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PREFACE

NOTE.—This Preface is reprinted without alteration from the last edition. In this edition, for the benefit of students, the historic outline of the origin of modern electric methods is given, together with illustrations and descriptions of methods which bring this book up-to-date. Latter-day methods cannot be estimated apart from their development, hence we place them at the end to secure the right perspective.

W. AND T. LEWIS

THIS edition of "Modern Organ Building" is substantially the same as the first. Some additions, however, have been made with the intention of increasing informative matter, and some parts rewritten to confine them more strictly to the subject.

What information these pages contain concerning organ-building—not a scientific or similarly related aspect of it—has been derived from no other source than everyday familiarity with its concrete expression—that is, from practical experience. No drawings reproduced in this book, with the exception of a few which are the subjects of patents, had been published previous to their inclusion in the first edition: some have been added to this edition.

Concerning tracker-work, it was not considered necessary to do more than mention it, and examples have been omitted to give space to those which have more claim on attention in point of modernity and present-day utility.

Where full-organ pallet resistance is so slight as to permit of a normal touch, it is but logical to consider the occasion for pneumatic agency does not exist, as its advantages under such circumstances are slight. Thus tracker-action would be confined to instruments of a size safely characterised as small, though not more exactly definable with equal brevity. But combined with an inconveniently heavy touch, the continued use of tracker-action is merely an

anachronism there is no necessity to tolerate in an old organ worth the cost of modernising, much less permit in a new one.

In the case of a wind instrument such as the organ, the application of pneumatic mechanism to control the speaking pipes was inevitable, and will, if present tendencies be considered sufficient indication of future developments, ultimately entirely supplant all means of control in which muscular energy is directly utilised as a motive force, and not simply as the means of calling into activity the potential energy of compressed air. Accordingly, all actions of a "mechanical" kind, still retained to some extent in conjunction with tubular-pneumatics, will finally disappear, as they have already in the more advanced applications of electro-pneumatics.

The supremacy of pneumatic action being beyond cavil, it naturally assumes first place in these pages, and but two points of cardinal importance need be mentioned here—in this Preface—concerning it: these are, the two means of control, (1) by tubes (tubular-pneumatics); (2) and by electricity (electro-pneumatics).

In the United Kingdom there are more organs built on tubular than on electro-pneumatic systems for reasons related to initial cost and expense of upkeep. The importance of tubular-pneumatics has increased of late years rather than diminished, owing to its association with electric control in instances where switch-board coupling has been passed over in favour of a more dependable tubular method. Hence arises a combination of electric control with one of the usual tubular-pneumatic systems: the latter, therefore, have a dual claim on attention. These reasons appear sufficient to justify our inclusion of a series of examples comprising the tubular systems known in the trade.

In the case of self-contained organs of moderate size, even if the two methods of control—electric and tubular—be considered equally reliable, it is possible to mention circumstances under which no *practical* advantage could be gained by the use of what must be, in the nature of things, an added complication, viz., electric control. This appears beyond reasonable contradiction, but whether it be accepted or not, there is no indication that tubular control will lose its present importance by reason of a narrowing of its sphere of application, except at a time still remote.

Anyone having the slightest knowledge of mechanism is aware there is no finality in any form of it, so it is to the underlying essentials that we would direct attention. Root ideas of organ action-work are not forsaken except over long periods, but the expression of them improves.

Proceeding from the root idea of tubular control, three principal variants are now used: these are, the tubular systems explained in these pages. These systems differentiate in ways mentioned in the context, and are subject to continual variation and improvement in detail, according to particular adaptations of them by builders.

Many variants of the root idea of electric control are now used. These, exclusive of the pneumatics which are adapted to them—the electro-magnet, armature, and valve in connection therewith being the electric control—may be indicated in a few paragraphs. No attempt is made at classification, except such as may be arrived at by a broad comparison of the types of electro-magnet and accessories in direct connection, as just mentioned:

(1). In the Hope-Jones system, electric control was applied to every action part, coupling being accomplished by switches. In this system the armature is also a disc-valve. For this reason the control is extremely sensitive—if we may venture the remark—too much so, judging by the slight causes of derangement.

In its later form this system has been used by several builders, up to the time of writing, other than the originator, although the Hope-Jones types of pneumatics are not necessarily involved.

Some may demur to this remark, and consider that if the Hope-Jones pneumatics be not used—or even if the system be subject to adaptation in any way—it should not be identified with the name.

Even if this be granted, it is doubtful if it can be rightly said of any electro-pneumatic system at present in use which includes electric coupling, that it owes nothing to the Hope-Jones system.

(2). Builders who do not use the type of control mentioned above, mostly prefer single or bi-polar magnets of the "bobbin" pattern, which actuate small double valves of the familiar pneumatic action type.

This is necessarily a vague statement, as the variation in arrangement and detail is such as to preclude any other. We regret that it is impossible to give illustrations of present-day electro-pneumatics except the Hope-Jones system, for reasons obvious to those acquainted with the reserve maintained on such matters.

The portion of this book dealing with voicing, etc., has been entirely rewritten. The "aero-plastic reed" theory of the cause of sound in flue-pipes, associated in these pages principally with the name of Hermann Smith, has been substituted for the brief explanation taken, in the first edition, from Tyndall's "Sound." Although tuning is reducible to mathematics, and the

phenomena of sound are explicable in terms familiar in mechanics, voicers rightly proceed by empirical methods, and in consequence remain undisturbed by theories which merely seek to explain facts. We have certainly not ignored the scientific side in these pages, but we have been reluctant to go beyond what may fairly be considered the province of the organ-builder.

Endeavour has been made to avoid unexplained technicalities, except to some extent in the Introduction, wherein it was considcred undesirable to anticipate explanations.

We have pleasure in recording our thanks to W. Stevens Jones, Esq., A.R.I.B.A. (Bristol), for his care and suggestions in looking over the matter added to and rewritten in this edition; and to the publisher for the readiness with which he has compiled with our wishes.

BRISTOL WALTER AND THOMAS LEWIS

CONTENTS

CHAPTER I

GENERAL INTRODUCTION. MECHANISM

CHAPTER II

SOUND-BOARDS

CHAPTER III

BUILDING FRAME, BELLOWS; FEEDERS AND CONTROLLING VALVES OF THE SAME, ETC.

CHAPTER IV

ACTION-WORK

CHAPTER V

ORGAN BLOWING

LIST OF ILLUSTRATIONS

TIME AND PROGRESS

AT the end of this book we have added two sections dealing with the latest methods of electric control and centrifugal-fan blowing, showing how these have reacted upon organ building. So this volume has unintentionally become a chronicle of change in methods of production. Organ building has been called the "art and science," but we take no responsibility for using the phrase: it is, of course, a trade, and cannot be carried on independently of the economic environment.

What is the "art" of organ building? Over a century ago—nearer two, perhaps—it combined what are now considered as two—the art of decorative design of the case, and musical art.

The organ case was designed and made by the organ builder, the carving being a recognised part of the trade. This practice wore away after the Renaissance, and was lost when students attempted to revive Gothic.

The musical side is fundamental and antecedent to instrumental music. It is the most obvious and least noticed part of the trade, so much so that we wonder how many who read this will know what we mean. It seems part of the craft is still a "mystery." In the organ builder's estimation, at least, whatever claims an organ may have to attention rest upon that part of it which is now lost to view of the public, and seems never to be discussed by the organ committee. You may read all the literature on the subject, and never find a specific reference that emphasises its importance. We have, indeed, read

some modern comments which reveal the extent of the misunderstanding where one would least expect it. Some day we hope to find time to say more.

Preparing a third edition affords an opportunity for considering some of the changes since the original was published. At that time electro-pneumatic and what is now termed unit or extension work were anathema, now they—or it?—is almost an anthem, not perfectly harmonised as yet. This is one of the changes. Is unit or extension work so much changed that what was formerly found wanting is now wanted? It has not changed, because it cannot. The method on the mechanical side has changed.

The portable console owes its existence to the fact that the Presbyterian churches were designed to exclude an organ—intentionally, at one time. Otherwise it is improbable Best would have had grounds for his jest—the cable should have been been put round the neck of its inventor.

Our view was to have excluded criticism and to have simply presented various methods without comment. We deferred to musical critics, however. On the whole, having done so, we see little beyond a few unintentional asperities we would wish to modify.

Musical and trade opinion went further than any remarks of ours concerning electric work and extension, and some indication of what it was is easily accessible in Dr. Hinton's "Story of the Electric Organ."

Hope Jones organs were superb examples of craftsmanship and material. It did not pay, of course. (How much organ building has ever paid?) "We shall make it pay when we get it systemised," said hopeful Jones. He made the mistake of not recognising any limitations. Couplers made the tracker organ unplayable, they were the obstacle to tubular control, they (and similar contrivances) spoilt the electric organ. The best organ ever built (whatever that may mean) would be none the worse, mechanically, without them. It has cost the trade enormous sums to develop on these lines.

The first contacts Hope Jones used had proved satisfactory in telephone work, in the organ they oxidised in a fortnight. In the cinema the organ was used nearly all day every day, in many churches it is used a little once a week. Time is not the same factor where a piano action was worn out in three months (when pianos were used) as it is in churches, where organs are seldom worn out by use, but by the conditions. In England they speak of their new organ five years afterwards when, in America, they would probably be talking about a new one. About two-thirds of the organs here are in rural areas, and it seems hardly necessary to do more than mention the majority of them were built before any kind of automatic action was generally practicable, and many before such was invented, to illustrate the prospects for universal electric organs in this country.

Hope Jones is so much a back number in the country of his birth that the younger generation do not recognise his musical voice. As the Anglo-American organ is largely the result of the direction he gave to organ building, it is necessary to follow the development of Hope Jones' ideas in order to find the link between mechanisation and the organ of tradition.

Hope Jones was what is now known as a business psychologist. One of his minor eccentricities was riding a bicycle—when they were novelties—dressed in a frock coat and tall hat, with an umbrella aloft on rainy days. Another was his mutual improvement class for the exchange of information on the craft, where the "exchange" was certainly favourable to him. He was a telephone engineer, a good organist, a fine leader, but not an organ builder. He collected ideas from all. He gathered round him many good craftsmen and was well liked until he introduced female labour into the Birkenhead factory. The long strike that followed was, eventually, the cause of his business activities here ceasing. Not long after he went to America and joined the Austin Company.

The first portable detached electric console in history was put to the rebuilt organ at Sefton Park Presbyterian Church, Liverpool.

during the ministry of Dr. Watson, of "Bonny Brier Bush" fame. It was fitted with ivory rocking-tablet stops, with coloured "pips" as indicators of the class of tone-quality—as reeds, diapasons, strings and flutes. Excepting the stops were not on an inclined plane, it was in exterior much as the most recent of consoles of the Anglo-American school. As being one of the few at that time with experience of electric organs, one of the writers had charge of making the console to the Hope Jones specification.

Some of the Hope Jones "specialties" were the floating disc-valve armature, electric coupling, the portable console, stop-keys with coloured indicators, key-touches that combined three movements, the stop-switch, the double touch on the manual (two levels of key resistance, which gave the possibilities of two manuals on one), the pizzicato touch (which automatically played staccato), extremes of wind pressure and scaling pipes, freak voicing, unit extension, diaphones, single-rise reservoirs with canvas tops, and the electric locking-switch for a free combination, and the automatic swell. Further, sectionalising the organ, as it displayed the novelty of the control, and "hanging it on a nail" on the wall, as he said, and distributing it about the building.

Shortly after associating with the Austin Company he issued a pamphlet adding a programme of a whole-hearted unit system in which the "foundation" was available at from 32ft. to the 2ft. pitch on one unit : he advocated all manuals enclosed in cement swell boxes with thermostatic electric radiators to keep the temperature constant : aluminium swell shutters with vacuum cavity : no soft stops, as the swell could reduce them : a new type of console with stop-keys on an inclined plane : pedal-board adjustable by turning a handle, together with the stool. In case anyone should object to playing these instruments he proposed to found a school of organists that would be educated without prejudice, and jobs found at a good salary.

He concluded by intimating that acoustic reflectors would eventually be perfected to overcome the deficiencies of swell boxes, and

proposed to abolish the organ altogether when his "electric vibrators" had become adequate to do away with pipes, which would certainly have made all his previous work sterile.

These few facts give an inkling of how much of the scientific appeal to progress we owe to the enthusiasm of the irrepressible Robert of twenty-five years and more ago.

Anything with any good in it was gathered from traditional organ building. Keen-toned string stops, good reed voicing, electric action, were not originated by H. J. The detached electric console, with electric stop control, began with the Bryceson brothers at Drury Lane. The Hope Jones scientific tonal scheme (in England) was suggested also by the Brycesons, who used large scaled pipes on the heavy pressure they found useful for electric work. The Bryceson Diapason and Clarabella became the H. J. "Phonon" and "Tibia." A scientific organ is about as reasonable as a scientific violin. No one individual ever invented a new system of organ building. It was an evolution.

What is an electric vibrator? And why should H. J. have wished to use them? The answer to the last is, to simplify production. To the first: an organ pipe is a pneumatic vibrator—i.e., a wind instrument. A reed is a mechanical-pneumatic vibrator. A piano-string, tuning-fork, violin-string—these are mechanical vibrators. The telephone and loud-speaker diaphragms are electro-mechanical vibrators. All sound-producers must be vibrators to produce vibrations of sound —i.e., aerial waves. The organ pipe has a system of music within it. Electric vibrators have not, they can only reproduce with more or less fidelity the primary sound producer, which, in music, is the musical instrument. The domain of science is not in art—it only follows after. The science of optics has never done any good to painting, nor has the science of acoustics done anything but follow the trail of musical art. The creation of science is knowledge. Even some theories of science respecting the musical scale and organ pipes are

wrong. It does not follow that analysis can be inverted to synthesise a work of art, with skill left out.

Electric vibrations are inaudible and intangible. All electro-mechanics of motion boils down to the electro-magnet and armature. To be audible electric waves must become mechanical vibration, and then aerial waves. So either your musical instrument must be on the principle of the sounding-board, as the harp, violin, piano—or it must be a resonator like an organ pipe. The gramophone and loud speaker use a pipe, the cone-speaker is on the principle of the sounding board.

You may believe the organ would be better brought down to one pipe, from which it started, but that is not really the point. It would not be a wind instrument, and it would be dependent upon a system of music outside it—that of the musical instrument.

The system of music represented by the keyboard was developed by the organ. Terms used in music such as the third, fourth, fifth, octave, originally meant the third, fourth, fifth and eighth pipe of the diapason—i.e., the organ scale.

Hope Jones decried pneumatic work with tubes, for several reasons. The automatic electro-pneumatic control was practicable before tubular control, many considering the latter never would be feasible. Dr. Albert Péschard took the initiative and sought the collaboration of J. S. Barker, who was in Paris with Cavaillé-Coll. The result was the Péschard patent of 1864 (illustrated herein). Hillborne L. Roosevelt learned of Barker, and so introduced electric control into America. Barker, in partnership with Verschneider, made the first electric control a practical success before 1870, when his factory was destroyed in the bombardment of Paris. Barker took out a patent on his own account (1868), subsequently acquired by Brycesons. The first organ was at Salon (Bouches du Rhone, France), 1866. There is a record that in 1908 it was still efficient (forty-two years). The second was at St. Augustin, Paris, '68. In 1898 the Barker electrics were removed by the aged Cavaillé-Coll. This organ

worked well for thirty years with little attention. Mercury contacts were used in early work. Others on the Continent and here used electrics before H. J., who, however, professed to know nothing about them. He claimed, however, to have made a distinct advance on his predecessors, by making electrics "simple, reliable, and cheap"—whereas in fact he made them intricate, unreliable and expensive.

Tubular pneumatics is an organ-builder's action, and can only follow experience in the trade. Hope Jones could not have designed a tracker organ, much less a pneumatic one. Nor was Barker in any better case. In proportion as the organ ceases to be mechanical and pneumatic will it be dismembered amongst the electrical industry as a sideline, as it was in America. The same thing happened with organ-blowing, so that now not only do people with no experience of organ building lay claim to a part of the trade in competition with organ builders, but they claim to be able to teach the latter. Not only so, the electrician with no knowledge or experience of mechanical engineering or organ building will contract for the work of organ-blowing.

Hope Jones' science decided tubular control had the inherent defect of wave-motion. He did not bring forward the fact that no automatic action transmits the touch of the executant. As he used pneumatics, his criticism is confined to transmission. Electricity is, of course, transmitted, but in fact its velocity of travel has nothing to do with the practical application of it as a moving power. In that case the result is not automatically secure, for, as with an electric motor, the load is picked up with greater or less speed in accordance with the capacity and kind of the machine in relation to the load. Electric action can be slow.

Sound, also, is wave-motion, and having overcome transmission one must wait for the wave-motion of sound, which is pneumatic although not tubular, to reach one's ear. Experience shows the cable creates as many difficulties as its theory allays. As to whether the acoustics of the building will interfere with the response can only be

decided by the event. At the moment there is an argument about this same thing in an instance where the console is not detached, yet some suggest improving matters by taking it further away.

By means of an automatic pallet used sometimes in voicing, it can be demonstrated the response of any pipe becomes continuous after a certain repetition is exceeded. The pallet can open and shut whilst the pipe sounds continuously. For this there are several reasons, one being that at about sixteen vibrations a second the ear is unable to distinguish separate impressions. To give an extreme example, the 16ft. open will not dance to the same tune as the lively Piccolo, although we have known it to be expected. It is to help the bass that octave pipework is used, as well as to augment the unison.

Hope Jones attained repute in about five years. That is, his factory employed about 200 to 300 men, and he secured contracts including cathedral work over the heads of established organ builders at prices far above what had previously been known in the trade.

Even in pre-war days some American firms had established a system of standardisation with pneumatic sound-boards, the bars being stocked completed, and the end cheeks cut to take whatever number of stops the specification required. Standardised organ building developed mainly in America upon the foundation of Hope Jones and Roosevelt. So we received back with interest what the public christened the Cinema Organ, not having seen it in recent years elsewhere.

The revival of "extension" is another change we record. A definition of what this means is, as far as we know, absent. The diapason is the standard of the organ—the fixed relation of open pipe-length to key. The unit chest, which includes all kinds of extension. is, theoretically, the opposite. That is to say, there is no fixed relation between the pipes on the unit and the keys. Any 8ft. might be extended by adding 12 pipes to bass, and 12 to treble, so it could then be played as an 8ft., as a 16ft., as a 4ft.—jointly or severally. To explain this we may regard an ordinary piano as a unit of strings.

If, now, we confine the extent of the keyboard to 58 or 61 keys, as with the organ, and for the sake of clarity suppose such a keyboard ready to connect automatically up to the piano, then all the connections straight across from the piano middle C to the organ keyboard middle C give the normal, or unison, or standard 8ft. pitch. Another set of connections from piano middle C transposed one octave to the treble of the organ keyboard, give the sub-octave, or the octave below unison pitch, termed 16ft. on the organ. Similarly, transposing the piano treble to the bass of the organ keys one octave, you would be playing the piano actually one octave above normal.

You may transpose organ music (written for the 58 or 61 compass of the organ) on the piano an octave to the bass or to the treble without mechanism, by playing it accordingly. Similarly, you might take an organ keyboard off that instrument and hold it in relation to the piano in the three positions named. To couple up the three positions simultaneously calls for mechanism.

It is not a system of organ building, but of playing the organ. It does, in effect, what Hope Jones set himself to do—turns the organ into the exact opposite it was before he found it. On the other hand, extension might mean no more than the octave on the Bourdon—the derived Pedal Flute. Probably few organs built this last twenty years have not one or two derived stops.

The old English organ had G $10\frac{2}{3}$ft. as the lowest manual note. The pedals connected on the Great bass. In order to make the instrument suitable for the German school of music—to play Bach, in effect—Dr. Gauntlett led the campaign which ended in favour of the short manual, full compass and independent pedal. It was unnecessary to claim independence for the Great manual, as it existed. The Swell attained independence of the Great by acquiring its own bass. If, however, the organ is to develop on the lines of the unit, no musical independence will remain even on one manual. In other words, it knocks the bottom out of the musical scale, which cannot exist except

as a fixed relation of pipe to key. This is not a matter in which the organ builder can swim against the stream.

In the super-cinema of America the organ was first a background for an enormous orchestra. The cinema, however, joined in the funeral procession following wherever the machine leads. As the orchestra became smaller, the cinema organ was marketed with two tracker bars in addition to keys. The tracker bar enables the organ to be played automatically by roll music. Two of these were arranged for the manipulator to operate a continuous programme—as one roll played another was prepared. Before this system had time to extend, however, the combined sound and motion film went a step further by having the music embroidered on the edge of the film, and the law being the survival of the fitter in the engineering sense, the cinema organ succumbed to the more hopeful Jones of another industry.

It should be understood standards of comparison in these pages are ideal—i.e., theoretic mechanically. A "perfect" result, or a perfect organ in the absolute sense being ruled out by that very general law of mechanics known as Compensation. That is, one extreme is attainable at sacrifice of the other. The characteristics of an art—or a craft—are its limitations. One difference between science and art is, that the former does not recognise limitations, although, of course, subject to them.

Before concluding, we venture to touch upon a matter related to our subject. It is not realised as widely as it should be that whatever beauty or utility there may be in manufacture owes its origin to the skilled hand. The other day we received a catalogue from a concern engaged in manufacturing products of moulded resinous compounds, the latest method of repetition work, and a somewhat similar comment was made in its pages, respecting the necessity of original work for the making of moulds, the high degree of skill demanded, and the cost. Quite a simple mould cost fifty pounds—one for a radio cabinet cost over a thousand pounds. There is no skill

in a machine—that is outside it, in the only place it has ever yet been found—in the human machine.

Mechanisation and progress are now considered almost exchangeable terms, but there are instances in which no one would admit the exchange to be an improvement, as in the case of one's limbs as nature formed them. It seems we have not improved on nature. We have read, it is true, a book with this same theme, almost, in which the author maintains the duplicate is as good as the original, and that mechanised art is equal to the hand mode. The point of interest, as we see it, however, is, for example, Who is the artist in such case?

If one pays for a seat to hear Mr. Solo Pianist, or Madam Contralto, a programme of gramophone records might not be deemed up to contract, and for all the eulogiums on labour-saving machines the audience expresses its appreciation by working the artist harder—by the encore. It could not be persuaded out of an evening's entertainment by a lecture on the benefits of leisure for the artist if he used a machine to speed up his recital in order to get home earlier. We are being serious with a trifling subject in order to show there are some instances in which mechanisation is not admitted to be progress. Logically, there is no reason why the artist should not serve the public on the same terms as industry, and likewise no merely logical argument why the craftsman should not scrap his tools in preference for the much less arduous and exacting work of minding the automatic press-tool. In such case, however, if there were no skilled work there could not be automatic repetition of it by the machine. If, then, as some say, the number of skilled hand workers is becoming smaller, surely we shall not meet this reduction of a national asset by the optimism of the ostrich, even if it is pessimistic to look at the facts.

Primitive music and instruments differ from modern in point of skill. One composer after another has set a higher standard of technique. In the constructional trades generally—as cabinet making, building, ship-building—there are limits to mechanisation probably

reached, if not exceeded. These are only consistent with a considerable amount of original work. Similarly with the organ. By that we mean not necessarily originality, but positive first-hand work, and not negative automatic work. If music is to be served by the instrument. there must be a system of music within it, hence it must be a product of first-hand skill.

Compared to art, mechanical science is an infant. All the arts had attained a developed form before mechanisation began. The organ scale was perfected in the time of Bach, since when it has not changed. Since then the organ has developed tonally. The music of Bach and Handel does not appear in relation to modern music as Watts' engine compares to a new turbine. Progress in art and mechanics is upon different planes, but from the spectacular advance of the latter it seems as though some consider art stands in need of "modernising." New arts probably call for a new humanity—a taller order than the discovery of a new source of power, or of another way of utilising an old one. Mechanical progress received successive impulses from the discovery of steam, gas, electricity, petrol. There cannot be anything comparable to this in art, nor can we visualise a future for mechanical progress as rapid as our time made upon the discoveries of the nineteenth century. In this respect we would modify our views, for time has revealed a sort of finality in mechanics —like the ball bearing, for instance, the induction motor and the turbine.

Mechanics—which all powers use—comes down to a few geometrical forms known when history began. Archytas designed machines of extraordinary power, and might have mechanised the Greeks (had they consented), but was dissuaded by his friend, Plato. Having attained a certain complexity, mechanism strips off all but "essentials" in the race against time, and becomes simpler and more automatic. The two are related now, both in production and the

product. Knowing the direction it travels, it begins to be possible to form an idea of how far it can go before the simplest and most automatic form can materialise. Mechanisation has a competitor now—"chemicalisation," or the "process." By means of the photo-electric cell the Americans are trying to chemicalise tone—the acid test of art! Mechanics is merging into chemistry.

CHAPTER I

GENERAL INTRODUCTION. MECHANISM

Sound-boards—Bellows work—Action work—Order of evolution of organ actions—The four kinds of actions—Supply and exhaust systems—Classification of actions according to their work and positions—Details of pneumatic actions

FROM the introductory matter comprised in this section the reader will realise the outlines and principles of a subject practically inexhaustible. Some selective process was, of course, essential to the production of a volume of moderate compass.

The first part deals with:

(a) Sound-boards (Chapter II)

(b) Bellows work (Chapters III and V)

(c) Action work (Chapter IV)

(a) Sound-boards.—These are for the dual purpose of support and control. They are sometimes referred to as "wind chests," a name more indicative of their office, for organ sound-boards do not act as resonators to the pipes mounted upon them. Soundness of construction and adequate support for the pipes are amongst the essentials. Sound-boards may be divided into two groups or classes, technically known as:

(1) Slide sound-boards.

(2) Sliderless sound-boards.

(1) The modern type of slide sound-board generally used by English builders was largely perfected by the late Henry Willis and T. C. Lewis.

Note —As the later portion of this volume (Chapters VI and VII) deals with organ pipes, and the production of tone, this note is the only reference made to these matters in this section.

As we think the preference still given to this type in England is well grounded, we illustrate it. There are other ways of making slide sound-boards which vary principally from the old type illustrated in having one small pallet for each pipe, instead of one large pallet for each note common to all stops.

(2) *Sliderless sound-boards* —These may be subdivided into two groups: those which have circular or rectangular pallets to admit air to the pipes; those which have membranes to fulfil this office. In both kinds the slide is replaced by the ventil, and each pipe has its separate pallet, or membrane, as the case may be.

The membrane, used as a valve to admit air to speaking pipes, is not entirely satisfactory, liable as it is to fluctuation according to the degree of atmospheric humidity. A pallet of adjusted invariable movement, actuated, preferably by a bellows motor, is better for this purpose. For this reason we have selected the Roosevelt type of slideless sound-board for illustration. The objection to membranes used as valves does not apply with such force to their use as motors actuating valves, but even in this capacity the bellows motor wherever it can conveniently be used, is preferable.

The slideless system, with purse motors, or membrane valves, is largely used on the Continent. The Roosevelt chest is widely employed in America.

(b) Bellows Work —Under this head comes all that belongs to the collecting, compressing, and holding in reserve the air necessary for action work and speaking pipes.

There are two kinds of bellows in general use:

(1) Single rise

(2) Double rise, with inverted folds (or inverted ribs, an equivalent term).

Both will be found illustrated in this book.

Of the small bellows known as "feeders," used to collect and force air into the main, there are three kinds used:

(a) Hinged

(b) Square-drop

(c) "French."

The first two *(a)* and *(b)* are illustrated in this book. The last *(c)* is used rarely, as it is not so adaptable It consists of two hinged or square-drop feeders arranged each side of a common centre board, so that by moving the last, air is compressed in the one and drawn into the other from the atmosphere.

(c) Action-work

ORDER OF EVOLUTION OF ORGAN ACTIONS

With but few exceptions, organ actions may be defined as the media of control between an organist and the pipes of an organ. According as they facilitate easy, rapid, noiseless control, eliminating fatigue to the organist, so must they be judged An ideal action would be one transmitting motion communicated by a player without loss of time between the act of causeation and desired result, and that would also always present an invariable resistance to control (i.e., touch of hands or feet), and at the same time, be noiseless.

In the order of evolution actions may be tabulated thus:

(1) "Mechanical" and tracker actions
(2) Part tracker, part pneumatic actions
(3) Tubular pneumatic actions
(4) Electro-pneumatic actions.

As we are dealing with the modern organ, numbers (1) and (2) may, we think, be excluded except in so far as they serve as an introduction to modern actions, and to such modifications of particular mechanical actions that survive in modern practice. Incidentally it should be noted that "tracker" action means—to an organ builder—that particular action designed to open pedal or manual sound-board pallets in tracker organs. A draw stop action of a tracker organ he would refer to as being "mechanical." This distinction has caused us to use the word "mechanical" in this limited technical sense as meaning those actions which communicate motion directly by arrangement of rods, rollers, squares, etc., other than key or pedal-board action.

Many builders still use a mechanical form of composition action, derived from a form used in old tracker organs, though generally changed out of all recognition—comparatively—to its ancestor. This composition action, a pedal coupler action, and a swell pedal action, are the only ones of this type that are likely to endure for many years. As they are still fairly constant in the fabric of the modern organ, we shall, of course, deal with them.

THE DIFFERENCES BETWEEN THE FOUR KINDS OF ACTIONS.

(1) Tracker and mechanical actions are those which bring pipes under the control of a player by various arrangements of squares, levers and connecting rods. They have one merit, namely, direct transmission of movement without loss of time. This statement, however, takes no account of "false" action, and is perhaps not strictly accurate,

but without splitting hairs it will stand as a general statement. Tracker actions are defective chiefly with regard to the extreme variability of resistance which they offer to control. This resistance may be stated as being proportional to the number of pipes controlled—the greater the number, the greater the resistance. The organist supplies the motive power, and in large organs the demand exceeds comfortable limits, and may even exceed his muscular power. The more pipes he brings under control, the greater his exertions become, and the more difficult it is to execute the deft finger movements entailed in rendering music.

(2) Part tracker and part pneumatic actions are those in which motors, supplied automatically with compressed air from the organ bellows, either assist or entirely relieve the organist from the muscular effort otherwise necessary. The so-called "pneumatic assistance" was first applied by Joseph Booth, an organ builder, to a tracker action working the manual sound-board pallets. (See Appendix B.) The Barker lever, invented by Charles Spackman Barker, was the first pneumatic action which relieved the organist entirely from the muscular exertion previously necessary to move the keys of any but a small organ. In this action, the tracker work was retained; it was operated by large motors, one for each key. The keys were attached to small valves, which supplied and exhausted the motors. The draw stop action, pedals, and composition action, were still "mechanical." In this action, compressed air from the bellows was the motive power, as with modern tubular pneumatic or electro pneumatic actions. Thus the work of moving the tracker action devolved upon the organ blower. His muscular energy, changed into compressed air, was merely released by the organist to effect the necessary movement of sound-board pallets. Hence the necessity in modern organs of many stops (in which compressed air sounds the pipes and works the action, not of the manuals alone, but the actions of pedals, compositions, draw stops, and perhaps the swell pedal) of machinery to blow.

Pneumatic assistances and the Barker Lever belong to the transitional stage between tracker and tubular pneumatic organs. The Barker Lever marks the beginning of a new era in organ building, and pneumatic actions have not yet reached their limit of development.

(3) Tubular pneumatic actions differ from the foregoing types by reason of the omission of all "mechanical" action arrangements of trackers, backfalls, squares or rollers used for the transmission of motion, this mechanism being substituted by a tube, which tube conducts potential energy in the form of compressed air to some form of motor. At the present time this describes but one kind of *tubular pneumatic* action. All kinds of *pneumatic* actions are now controlled either by tubes or insulated wires—the latter in the case of *electro-pneumatic** actions.

In modern tubular pneumatic actions, the tube may be compared to a nerve. A nerve (or, more correctly, some nerves) conducts an impulse to a muscle, which contracts, expending energy stored up in it. The nerve impulse is not the source of muscular energy, but the cause of its release. The same with the tube and the pneumatic action. The analogy is not perfect, nervous energy and muscular energy differ in kind as well as degree, whereas the difference is one of degree in the tubular pneumatic action. With electro-pneumatic action the analogy is perfect, inasmuch as there is difference of kind and degree between initial impulse and result.

The reasons for tubular pneumatic actions having replaced mechanical ones may be summarised in the statement that they eliminate fatigue to an organist. Invariable resistance to control, and facile control, are ultimately reducible to this statement.

In the nature of things, it cannot be claimed for them that they effect instantaneous control, for the speed at which motors work and

* The reader will find the evolution of the tubular pneumatic action dealt with under the heading "Auxiliary Machines," where it is used in explanatory form leading up to an understanding of the modern three-motor type of action.

air impulses traverse tubes is a matter of velocity, and (frictional resistance apart) such velocity is proportional to pressure.

(4) Electro-pneumatic actions are those in which some form of pneumatic action is controlled by a magnetically moved valve,* electricity being conducted along a wire to the magnet. Being placed in circuit broken at a key, pedal, stop key, or other control device, the magnet is capable of being energised at the will of an organist when he completes the circuit by moving the control device.

Electro-pneumatic actions are seemingly the ultimate expression of action development. They surpass tubular pneumatics in the facilities for control which they offer, and again in the practically instantaneous communication between console and organ. The outstanding problem facing organ builders is that of finding a durable and reliable "contact." At present tubular pneumatic actions occupy the superior position on account of their reliability and durability.

SUPPLY AND EXHAUST SYSTEMS

Tubular pneumatic actions come under two generic designations:

Supply system actions

Exhaust system actions.

To exhaust a motor means to allow compressed air contained by it to escape, so that the pressure inside the motor falls to the normal atmospheric pressure, or to a lower pressure than the air exterior to the motor.

To supply a motor means to raise the pressure of air inside it, above that of the air exterior to it.

* As far back as 1852 Dr. Gauntlett patented an electric action intended to open main pallets without the agency of pneumatics. For reasons that cannot be entered into here, this system was, and still is, unpractical.

These terms have the same significance applied to tubes, or any other part of an organ that may be said to be supplied or exhausted.

Supply actions were invented and developed to a considerable extent before exhaust actions. We do not include "suction" actions in this classification (actions in which the normal atmospheric pressure is utilised as the motive power, acting against a lower pressure artificially induced), as they are practically obsolete in organ building.* We are not aware of any builder who uses them except as they have survived to a modified extent mentioned later in this book (see page 87).

Actions on the supply system and those on the exhaust system may be further subdivided each into two groups. In the absence of distinguishing names it will be convenient to refer to them as supply system (A) and its modification (A^1): exhaust system B and its modification (B^1).

The supply system

This term derives its significance from the fact that when a key, draw stop, or other control is put "on" a tube is supplied. When the control is reversed, as in thrusting a stop "off," or releasing a key, the tube is exhausted. A supply action is, then, supplied "on," and exhausted "off."

This defines the generic term, supply system, as applied to actions under tubular control. In the absence of tubes, as with electric control, a supply action would be one in which the small motor, governed by the magnetic valve, was supplied for the action to be "on," and the reverse would hold good in the case of an electrically controlled exhaust action. But in the absence of tubular control, the terms supply or exhaust indicate very little difference in the actions concerned.

With tubes an important difference between the supply and the

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* "Suction" actions are utilised in "player"-pianos.

exhaust system is noticeable in console mechanism, especially in coupling chests and key actions.

The two methods of adapting the supply system differentiate thus:

(A) With one method, to which we will refer as supply system (A), tubes are supplied and exhausted from the control end of the tubes at the console.

(A^1) With supply system (A^1), tubes are supplied from the control at the console, and exhausted from the opposite extreme, usually through minute perforations in the auxiliary motors.

The exhaust system

The exhaust system is an inversion of the supply system. This means that tubes are exhausted to bring actions "on," and supplied to put them "off."

This applies to actions on the exhaust system in general. The differentia are:

(B) With exhaust system (B) tubes are exhausted and supplied from the control end at the console.

(B^1) With exhaust system (B^1) tubes are exhausted from the control end at the console, and supplied from the opposite extremity through a minute perforation in or at the auxiliary motors, with which the tubes communicate.

These modifications (A^1), (B), and (B^1) are such of the original supply system (A), and evolved in the order given.

Exhaust system (B) is no longer used in connection with manuals and pedals, therefore we do not include any example of a key action on this system.

With the exhaust system it is essential that tubes and control mechanism generally be sound, i.e., without leakage, as far as this is possible. Coupling chests must be well and effectually "bedded," and plentiful use made of screws. Grooving in wood should be avoided wherever possible, as in examples of exhaust key actions shown in this book, in which all tubes are continued up to the pallets. Tube plates should be bedded in the usual way, and the tubes after being inserted, should be opened out with a tapered dowel or other convenient tool, and planed level.

With the supply system avoidance of leakage is no less vital, but the manifestation of the defect in this case takes the more subtle form of retardation of attack, whereas with the exhaust system it takes the form, diametrically opposite, of cyphers.*

Modification represented by (B^1) lends itself to couplers, which may be multiplied, not *ad infinitum*, it is true, but to a greater extent than is possible with the other variations, with which every coupler is a brake upon the air passing through the coupling chest, or where this is not the case, every coupler added increases the demand upon the supply from the key action.

By suitably combining the two systems, so that key action and couplers are on the exhaust system (B^1) and auxiliary machines are on the supply system (A) or (A^1), it is possible to obtain a sum of advantages minus defects. This may be easily accomplished by passing the tubes through a relay machine, mentioned later in this book (see page 57).

Before proceeding further, it will be well if we define the terms auxiliary, secondary, and primary, as applied to motors in this book.

(A) Auxiliary motor, the smallest and one first moved of two or more related motors. The helper of (B) or of (C).

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* A "cypher" is a continuously sounding note.

(B) Secondary motor, second to (A) in size, moving next after (A) It is actually as much an auxiliary as (A), standing in helping capacity to (A) and (C), which could not perform their functions effectively without it in all cases where it (B) is used. To avoid confusion we have consistently referred to (B) as a secondary motor.

(C) Primary motor, the largest of two or of a series of related motors, in which the movement of a pneumatic action terminates.

We have varied this nomenclature from that in use amongst organ builders, who refer to (C) as a main motor, and to (A) as a primary motor. Also, a practice liable to cause confusion did we adopt it, motors (A) and (B) are both sometimes referred to as auxiliary motors, meaning thereby that they form part, when so called, of an auxiliary machine.

The significance attached to (A), (B) and (C) above has no application to *lettering* on the drawings in this book. This has no other significance apart from its utility as a reference to check explanations. The letters placed *underneath*, denote to which system of pneumatics the actions belong in a way explained on a subsequent page.

CLASSIFICATION OF ACTIONS ACCORDING TO THEIR WORK AND POSITION IN THE SCHEME OF CONTROL *

A further classification of modern organ actions, not restricted in all cases to purely tubular pneumatic or electro-pneumatic kinds, may now be attempted, according to the special work they are designed to accomplish as units in the general scheme of pipe control.

* At least one example of every action in this list is contained in Chapter IV.

A

Actions which control sound-boards directly, and consequently pipes, are:

1. (a) The manual draw stop machine, in the case of a slide sound-board: the ventil where the sound-board is of sliderless pattern.
   (b) The pedal draw stop machine or ventil (usually a ventil).
2. The manual auxiliary machine.
3. The pedal auxiliary machine. (Usually an integrant of a pedal sound-board.)

B

Actions which control pipes indirectly by controlling the machines named above are:

1. (a) The manual draw rod or alternatively stop key action.
   (b) The pedal draw rod or stop key action.
2. The manual key action and couplers.
3. The pedal action.

C

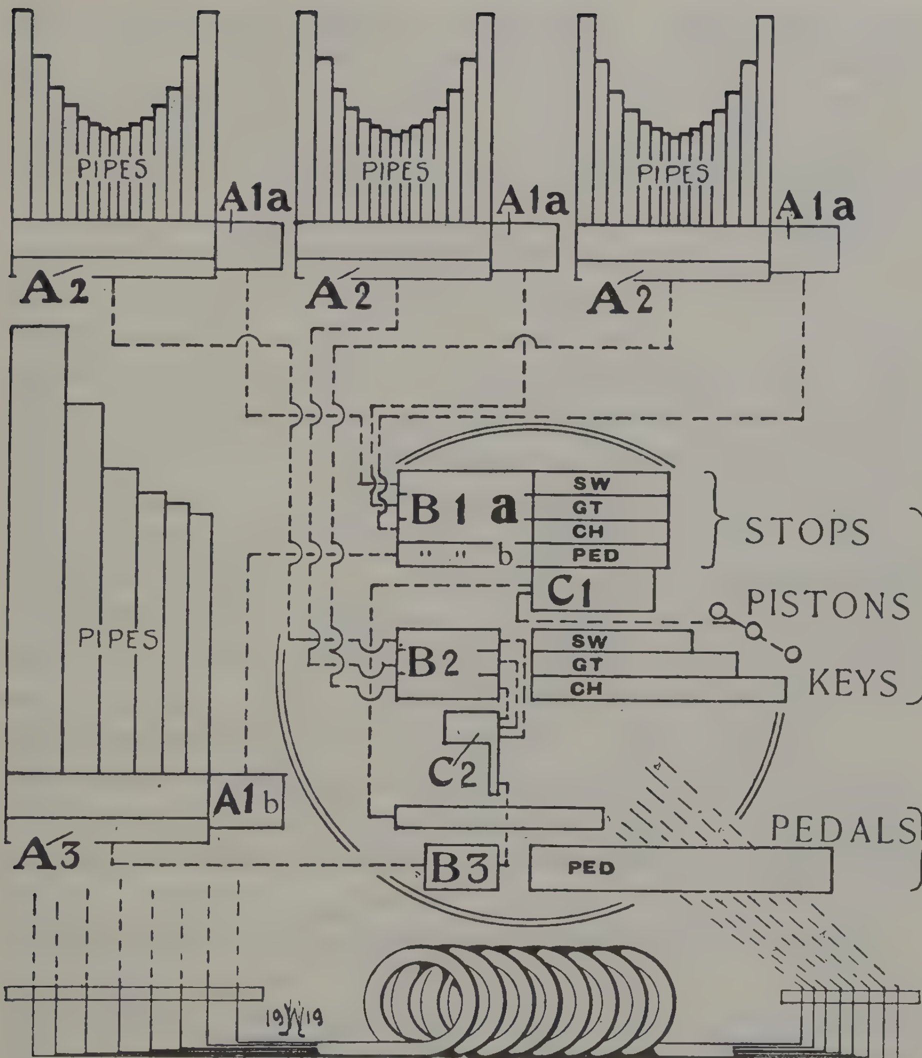
The actions which still more indirectly control pipes through the intermediacy of actions B (1a) and *b* and (2) above are:

(1) The composition action and (or alternatively) the piston action.

(2) The manual to pedal couplers.

Actions under letter C control those under B of corresponding numbers; those under B control those under A of corresponding numbers. Actions under A control sound-boards, and consequently pipes; actions A (1) *a* and *b* relatively (chiefly) to timbre; actions A (2) and (3) relatively to pitch. This may be expressed again by saying actions A (1) *a* and *b*, control stops of pipes, whilst actions A (2) and (3) control notes.

The term "machine" is usually adopted by organ builders as a



DIAGRAMMATIC REPRESENTATION OF A THREE-MANUAL ORGAN

The manual speaking pipes are represented standing on three sound-boards at the top of the diagram, the pedal pipes underneath. A2 indicates the position of the action work necessary to open pallets for the admission of air to the speaking pipes. Parts lettered A1a indicate action work necessary to bring under control stops of pipes.

The dotted lines represent "lines of communication" taken by bundles of tubes which link up the dispersed sound-boards carrying pipes, to the centre of control, the console, represented inside the circle.

In the instance of electric control the bundles of tubes are replaced by a cable of many insulated wires bound together, so effecting communication between console and sound-boards.

substitute for "action" when referring to (A) 1, 2 and 3, although of course these "machines" are as truly called actions.

The Poppet pedal we have classed with composition pedals. Composition actions and piston actions are identical as regards mechanism,* differing in the means of control offered to an organist—hand or foot control.

Modifications to the above scheme of control in modern organs occur when: (C) 2, the manual to pedal couplers, do not control the manual keys, but act more directly by these couplers being made as an extension of (B) 3, the pedal action, in the same way that the coupling is effected in the manual key action. In such cases the manual keys do not move when the corresponding pedals are depressed, as the control is shifted from a separate manual to pedal coupling action, of a tracker ("mechanical") kind, to a purely electric or pneumatic kind, working through (B) 3, the pedal action. This is one modification. Its effects are: manual keys do not move when coupled to pedals: sub and octave couplers on the manuals are without effect when manual notes are played from the pedals.

A second modification concerns the composition pedals, which may be arranged to achieve direct control on the draw stop machines, without first moving the draw rod or stop key action. This arrangement leaves an organist without any visible indication of what stops the composition pedals or pistons affect.†

Both these modifications are undesirable to the majority of organists, and are only partly necessary in electro-pneumatic organs where the console is so far detached from the organ that it is practically impossible to convey to it from the bellows the motive power of such actions, i.e., compressed air. Where, in an electro-pneumatic organ, such is the case, the composition difficulty is frequently overcome by some form of "suction" action, mentioned later in this book in due

* That is, consistent with any particular system adopted.

† An easy method of applying composition movements, in which fans are dispensed with, utilised largely on the Continent.

place. The usual manual to pedal coupling action, which in pneumatic organs is, in esentials, " mechanical," and a survival from tracker organs, would be too much of an anachronism to perpetrate in an electro-pneumatic organ console far removed from wind supply. For the sake of unification of control it will be allowed to this modification of the usual scheme as outlined, that it is permissible only where necessity dictates. We think the majority, if not all, organists will concur in this.

A third and minor modification occurs when stops of pedal pipes are brought under control, not by draw stop machines working slides, nor by ventils supplying sound-boards, but by slides in the pedal action (B, 3)—(see diagram). These slides cut off the tubes controlling pedal auxiliary machines. This method is only possible with the supply system, and it made applicable by the fact that owing to considerations of space and acoustical reasons, pedal stops are generally placed separately, each upon its own sound-board. This necessitates, with tubular control, separate sets of tubes, one set for each stop of pipes, and advantage is sometimes taken of this to cut off these tubes by slides in the way mentioned. This modification, perhaps, merely concerns organ builders, but it may be mentioned that under such conditions a cypher on a pedal sound-board, when it is caused by some derangement exclusive of the pedal action at the console, will persist, in spite of the stop affected being put " off."

All actions of class (A), (B) and (C), as arranged, are interior mechanism.

Those under (A) are part of, or in immediate proximity to sound-boards. Those under (B) and (C) are parts of the organ console.

(B) and (C) control (A), the organist controls (B) and (C).

Console mechanism is represented exteriorly by:

Hand control: key-boards, draw stops (or, in place of the latter, stop keys) and pistons.

Foot control: pedal board, composition pedals, poppet pedal.

By way of completing the list of "accessories" to control, the "Sforzando" pedal might be included, were it not for the fact that it is not generally used.

In the event of its inclusion, the "Sforzando" pedal would come under B in the list of actions, as it would control draw stop machines direct. Externally it takes the form of a flat balanced pedal, identical with a balanced swell pedal. Upon being moved gradually it brings on one stop after another,* from the softest to the loudest; reversing the movement has, naturally, the opposite effect:

The swell pedal and tremulant represent actions which do not come under the definition adopted for convenience of exposition. These are dealt with at the end of this chapter. The swell action controls sound, as does one form of tremulant.

As far as pipe controlling actions are concerned, the list given is complete, inclusive of the accepted "accessory" actions, compositions, pistons, and great to pedal "on and off."

As we wish to keep this book within moderate dimensions, it is impossible to give examples of all these actions as they vary in connection with the two supply systems and one exhaust system of tubular pneumatic work as used in modern organs. Neither is this necessary, for there is but slight difference between auxiliary actions and the like designed for the same work but on different systems. The main point of divergence in construction between the supply and the exhaust system is a trivial one if we exclude key actions and manual couplers.† It is this: with the supply system, the auxiliary motor is nearly always placed upon the exterior of action boxes. Therefore, in any case, by suitably placing the auxiliary motor, any pneumatic action may be

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* And all couplers.

† Examples of key actions and couplers corresponding to the three tubular systems A, A^1 and B^1 are presented in this volume: the system represented by B is not used in this connection, but only sometimes for draw-stop machines.

adapted to the supply systems (A) and (A^1), or the exhaust systems (B) and (B^1), referred to under the previous heading, "Supply and Exhaust Systems."

All diagrams of tubular pneumatic actions, it should be noticed, have an indicatory letter, A, A^1, B or B^1, placed underneath them to show the system to which they belong, in conformity with the meaning attached to these symbols on pages 8 and 9.

DETAILS OF PNEUMATIC ACTIONS

The mechanism of pneumatic actions consists of arrangements of (A) motors, (B) valves, (C) springs.

(A) *Motors*

These are of four principal kinds. (1) Hinged, opening like a book. (2) Hingeless, opening equal and parallel. (3) Ribbed, with paper or cardboard, after the manner of large bellows. (4) Ribless. They may be of any convenient size or shape. They may be double acting, i.e., two placed together so that they open in opposite directions.

(1) Hinged motors are used where rapid movement is essential. (2) Hingeless motors present a greater area to the wind than hinged motors, given equal area of tops, and are used where space is restricted to obtain power. (3) Motors are ribbed when they are placed outside action boxes, so working in the atmosphere. The ribs prevent the sides blowing out. (4) Ribless motors are used inside action boxes.

(B) *Valves*

Valve and pallet are synonymous terms. Pallets in pneumatic actions are of three principal kinds. (1) Single. (2) Double. (3) Inside pallets.

(1) Single pallets are used simply for supplying air, where no exhaust is requisite, as with those supplying pipes in the Roosevelt Chest. (2) Double pallets supply and exhaust and consist of two single pallets

acting in concert, as in most pneumatic actions. (3) Inside pallets are double, but are placed inside a boring, as the example given on Plate 20, Fig. 2. They are quieter in working than the others, but pass slightly less air in a given time proportionally to area than the previous kind.

Pallets in pneumatic actions are usually flat discs of felt faced with leather and backed with cardboard. To ensure against leakage, the backing disc is made of the same diameter as the hole covered by the pallet, as will be seen from the drawings in this book. Double pallets are secured upon threaded ("tapped") wires by means of leather-buttons, thereby being adjustable.

(C) *Springs.*

Five kinds of springs will be found illustrated upon action work in this book : (1) leg, (2) coil, (3) plain, (4) spiral, (5) flat.

(1) Leg springs are not easily adjustable, being similar in action to sugar tongs. Principally used with sound-board pallets supplying pipes. (2) Coil springs consist of a coil of wire of one or more convolutions as a continuation of a slightly curved wire. As will be seen upon Plate 20, Fig. 1, they are secured by a screw and washer which permits of the tension being adjusted. (3) Plain springs are curved wires looped at one end, being secured in the same way as coil springs. (4) Spiral springs may also be called coil springs, and are of close spirally wound wire. Example Plate 27, attached to the composition pedal. (5) Flat springs are thin narrow strips of steel. Used in connection with very small pallets, they allow of each pallet being perfectly registered with the hole it covers. Examples Plate 18. They are perfectly adjustable.

Springs used in connection with delicate valves must necessarily be of slight substance. Piano wire is generally used, offering, as it does, good material in graduated gauges.

Some small pallets illustrated in these pages, it will be noticed,

are without the small hemispherical leather buttons used to secure the larger kinds. In such cases they are made of leather or wood, suitably faced with "bedding" leather, or preferably the "bedding" leather is glued on the action box in a continuous strip, perforations being made at the valves. Such valves are secured on the ordinary tapped wires, no buttons being present to interfere with rapid supply and exhaust, an essential point necessary to be considered with regard to small work.

CHAPTER II

SOUND-BOARDS

Oldest type of sound-board—Pallets—Upper boards—Pipe racks—Explanation of slide movement—Scoring—Runnings—Leathered tables—Robbings—Flooding sound-boards—Tests for a slide sound-board—Roosevelt sound-boards—Explanation of the terms "motor" and "pallet"—The newest systems of sound-board construction—Pedal sound-boards—Borrowing pipes—Grooved basses—Planting pipes—Reeds—Faults in the speech of pipes due to bad planting—Sympathy—Off note blocks, why necessary

FROM time to time, innumerable varieties of sound-boards have been invented, and for a time used. For the most part, however, they have failed to satisfy the demands of practical utility, and have, therefore, ceased to exist.

The sound-boards that have successfully withstood this test may be counted upon the fingers of one hand We propose to illustrate two of these.

The oldest type of sound-board, shown upon Plate 1, is one of them. Without discussing its good and bad points here, we may say that its one outstanding good quality is extreme reliability. If well made, of first-class materials, nothing appears to upset the even tenor of its way, except, perhaps, extreme heat and damp.

The pallets, of which there is one for each key upon the manual, when opened by some form of action, admit wind into the groove between the bars of the sound-board. From the groove the wind rushes through the table, slide and upper board, and so into the pipes.

The pipes are arranged in tiers or ranks, one behind another. In the drawing, it will be noticed that the parts lettered "upper board" are of no great width, each one being reserved for a single stop of pipes

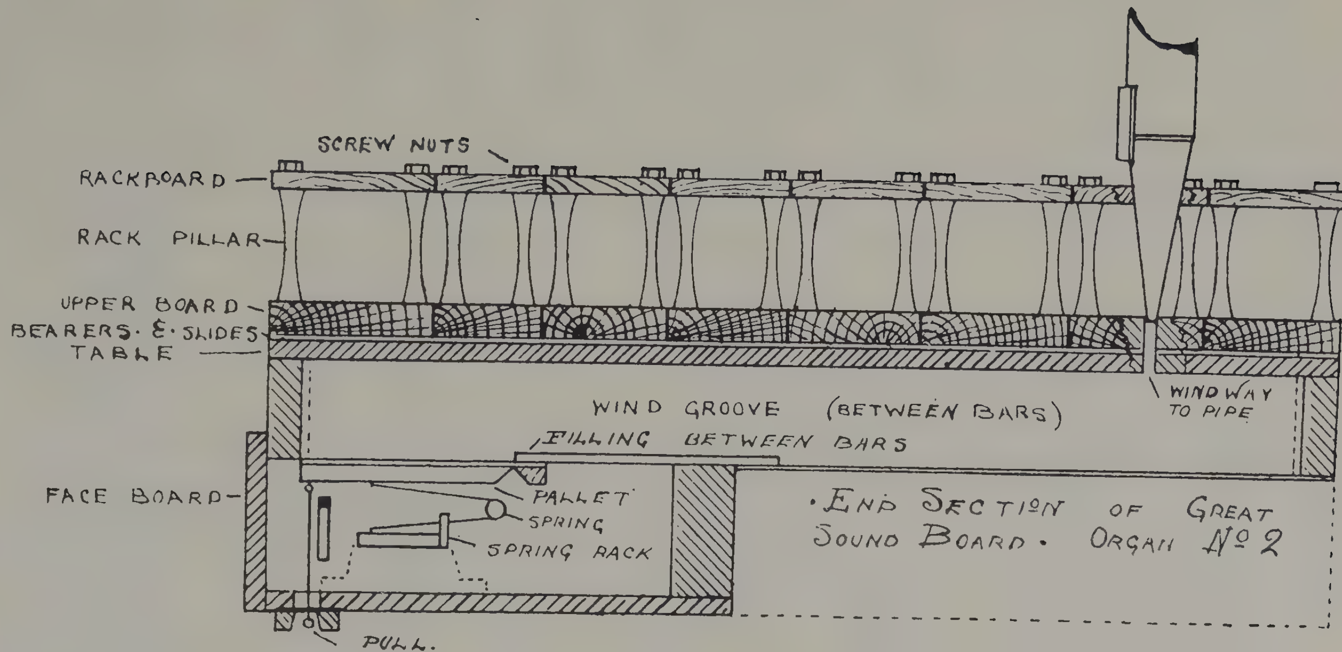


Plate 1

END SECTION OF A SLIDE SOUND-BOARD. [*Organ No. 2*]

This is a precautionary measure. Firstly, in the event of the slide becoming tight, the upper board may be removed, and the trouble located. Secondly, a narrow board does not shrink to such an extent as does a wide one.

The pipes, it will be noticed, stand in racks. The racks are supported upon small wooden pillars, screwed into the upper board, and secured with a nut through the rack itself.

The various stops of pipes are shut on and off by means of the slides.

In each slide is a number of holes, of suitable diameter, one for each pipe. These holes correspond, when the slide is at the on position, to similar holes in the upper board and table. In this position there is a free passage for the air under pressure from the pallet directly into the pipe. Upon the slide being pushed into the off position, that is to say, moved along about three-quarters of an inch, the solid part of the slide between the holes is interposed cutting off the supply. The pipes may thus be combined in stops or used singly, as the player wills.

Readers familiar with the working of the slide valve in engines will readily understand this. A parallel instance may also be seen in the sliding ventilators used in some railway carriages.

In order that they may be moved freely on and off, these slides must fit as loosely as possible in the sound-board consistent with soundness, i.e., without permitting the escape of air.

In practice, it is impossible to completely avoid such leakage, so one or more shallow scorings, similar to an oil groove in an engine, are interposed between each separate hole, both in the upper board and in the table. These scorings carry off any superfluous air that would otherwise find its way into adjacent pipes, and so cause "runnings."

Some organ builders (notably Germans) cover the table of the slide sound-board with leather, their object being to entirely do away with leakage at this point. In this they are generally successful, but as often as not they also succeed in increasing the amount of friction, making the slides difficult to move; so what is gained in one way is lost

in another. If a sound-board is made correctly, there is not the slightest need for this precaution. Well-fitting slides, black-leaded and polished, working between similarly treated surfaces, give the maximum of soundness with the minimum of friction.

Other defects, although not peculiar to, but frequently met with in slide sound-boards, are robbings. They are due to one or more pipes appropriating part of the supply of air due to others, with the result that those deficient are thrown out of tune.

Besides loosely fitting slides, another and more serious cause of running is a defective joint between the bars of the sound-board and the table. This can only be effectually cured by dismantling the sound-board and "flooding" it, i.e., pouring hot glue between the bars.

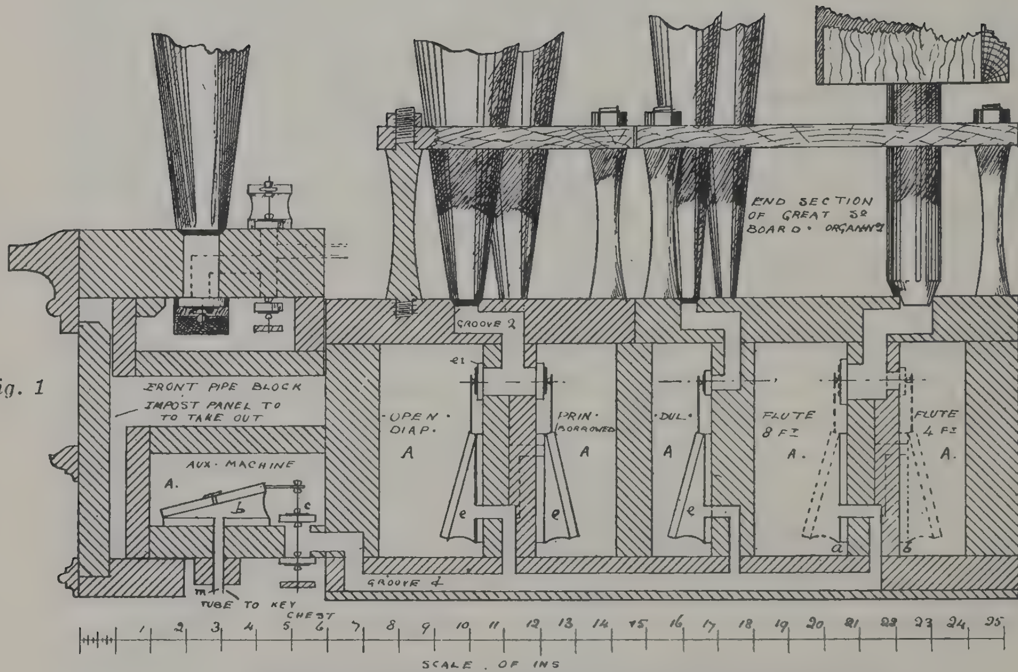
To test the sound-board for runnings, hold a few chords. If a few dissonant undertones make themselves audible in addition to the notes held, the sound-board is defective. Frequently, the defect may be of no very serious nature. The upper boards may have cast and twisted slightly, or the slides may be too loosely fitting. These defects are easily remedied.

The slide sound-board is the embodiment of the development of polyphonic music, in which the independent parts call for a means of realisation by speaking-pipes not only mechanically independent, but also musically extant. The standard demanded, although happily not limited to but one part of the organ, is now probably without a serious rival in any other kind of woodwork.

THE ROOSEVELT SOUND-BOARD

The Roosevelt sound-board, or, as it is generally called, the Roosevelt chest, is pre-eminently a pneumatic sound-board. Before attempting to explain it, therefore, perhaps it will be as well to obtain a clear idea as to what the terms "motor" and "pallet" mean as applied to pneumatic organ work.

Fig. 1



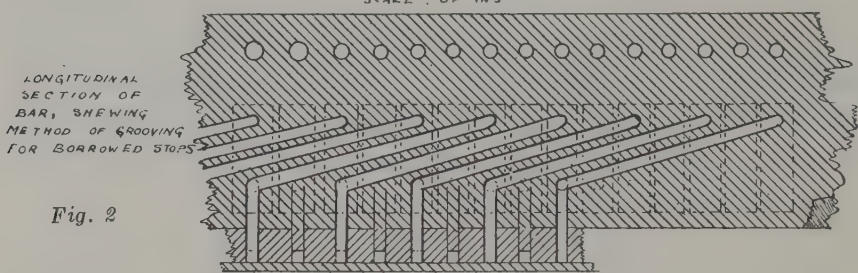


Fig. 2

Plate 2

END SECTION OF A ROOSEVELT CHEST. [*Organ No. 1*] **EXHAUST SYSTEM B**[1]

Fig. 1. End section. Fig. 2. Longitudinal section of a bar, showing grooving for borrowing pipes. The motors are shown in dotted lines.

A motor is essentially a moving part. It is generally accepted to mean two small pieces of wood covered with thin leather in such a manner that they may be inflated or deflated as required. They are literally small bellows

A hinged motor is one hinged like a book, opening, when inflated, in the same manner.

When a motor is said to "open square," it is made to open to an equal extent upon its four sides. i.e., without a hinge.

They are constructed both rectangularly and circularly, of all imaginable sizes.

A film of leather, covered over a hole in such a manner that it may be bellied out or sucked in is also a motor, although this form is generally alluded to by the term membrane or purse.

A "pallet" is some form of valve, governing the inlet and outlet of air.

It may be either a flat piece of wood, covered with felt and leather, as a slide sound-board pallet, or it may consist of a piece of felt sandwiched between a disc of cardboard and one of soft leather, as in the following examples. (See Plates 2 and 3.)

The details of construction of a Roosevelt chest are given in Plates 2 and 3. No slides are used, each stop having a separate compartment in the chest. Each compartment is supplied and exhausted of air by a ventil, which thus usurps the office of the slide. There is one circular pallet, of proportionate size, for each pipe.

The action (Plate 2) is as follows: the tube is exhausted of air when the key is depressed. The chambers *A* being full of compressed air, the hinged auxiliary motor *b* is collapsed, reversing the double acting pallet, *c*, and so opening the groove *d* to the outside atmosphere, into which the motors *e* are promptly exhausted. These motors take with them the pallets to which they are attached by means of the long screw eye (*e*1) so uncovering the grooves which communicate with the pipes.

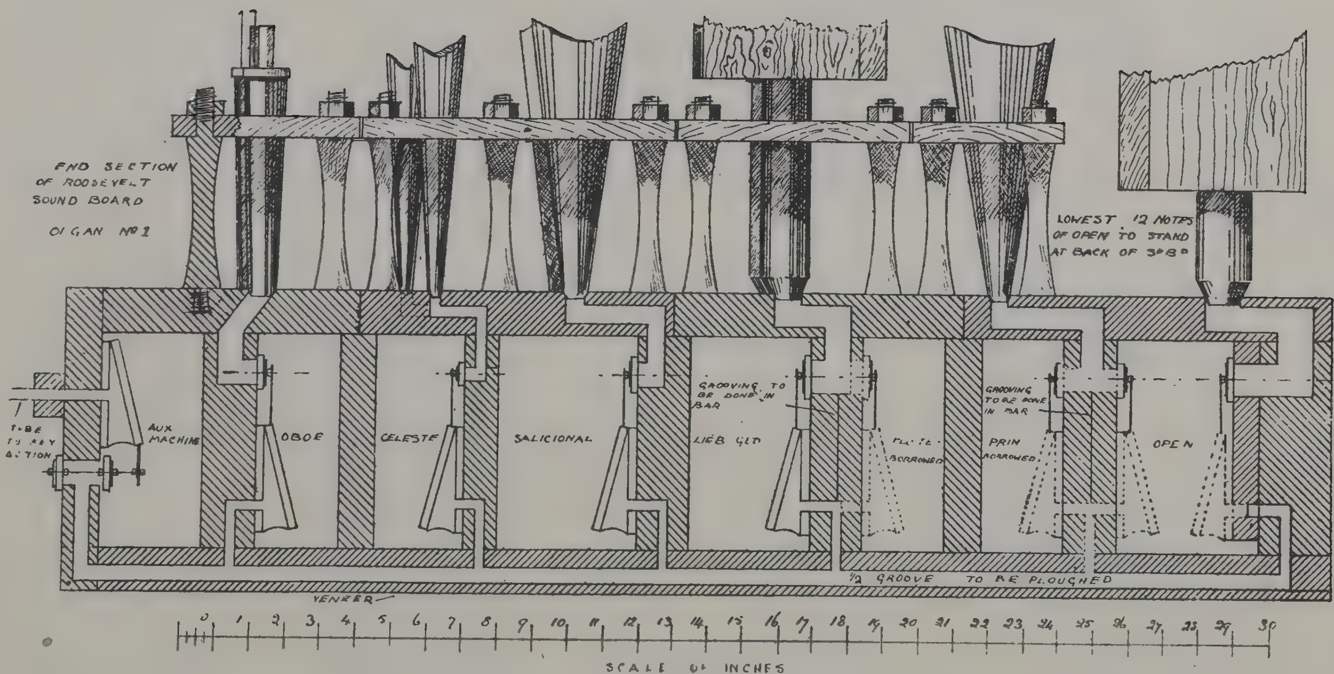


Plate 3

END SECTION OF A ROOSEVELT CHEST. [*For the Swell of Organ No. 1*] EXHAUST SYSTEM B[1]

The key now being released, the auxiliary motor *b* recovers the position shown upon the drawing, filling up by means of the tiny supply or "bleed hole," in its top. The air in the motors *e*, and in the chambers *A*, now being at an equal pressure, the pressure upon the pallets *e*1 closes them as shown in the section, being assisted by a light steel wire spring in so doing.

The explanation of these movements is, of necessity, somewhat lengthy and involved, but it must be distinctly understood that they all occur in the fraction of a second, or as fast as the key is touched.

Upon the stops being thrust off, the chambers *A* are exhausted of air under pressure, the motors, with the exception of the auxiliary one then being unable to move.

THE NEWEST IDEAS IN SOUND-BOARD CONSTRUCTION

The diagram, Plate 4, illustrates a new departure from the recognised system of sound-board construction. As will be noticed, it is

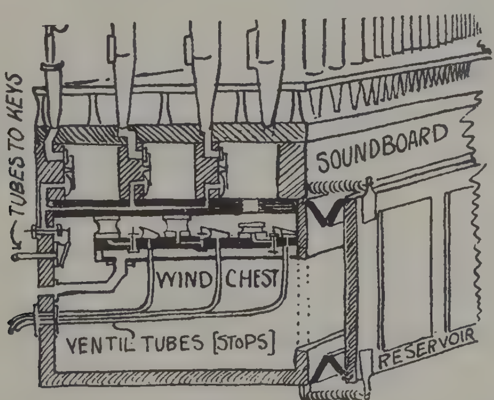


Plate 4

WIND CHEST

not a working drawing, being only intended to illustrate the principle employed.

The upper part, lettered "sound-board," is upon similar lines to the previously described Roosevelt chest The part lettered "wind

chest," is simply a huge box; upon one side of this air chest, and in communication with it, is a reservoir, extending the whole length of the chest. The chest is supplied with air under pressure from a reservoir and feeders situated outside.

The idea of employing this style of chest is to ensure that each and every pipe shall be supplied with air at the same, and at an unvarying pressure. The "universal air chest" system of building (America) is based upon this principle.

It has been employed in England with modifications, meeting with varying success.

This style of chest has given rise to a system of building in which the action work of the several sound-boards is enclosed in one common air chest. Needless to say, complications occur in its application to large instruments, restricting its use at present to comparatively small examples

PEDAL SOUND-BOARDS

Most up-to-date pedal sound-boards are constructed upon the Roosevelt system, and are sliderless. Unlike the manual sound-board of that name, however, they generally have an auxiliary and a primary motor for each pipe.

Sometimes, as on a pedal open diapason sound-board, the disc pallet is replaced with a rectangular one operated by a hinged motor, similar to some examples of manual sound-board pallets.

Two examples of pedal sound-board action are given, both upon the Roosevelt system (page 29). Fig. 2 is the supply action, Fig. 1 the exhaust. The drawings, we think, will explain themselves.

Some pedal pipes, stopped pipes especially, have a tendency to sound their first harmonic before settling down upon their fundamental note. Generally, this may be obviated by grooving the pipes, so that the wind has to travel through a channel before it reaches them.

BORROWING PIPES

On Plate 2 is shown a method of borrowing on a Roosevelt sound-board. The bar *ab* is built up of two thicknesses of wood, with a groove alternately in the one piece, *a*, and the other, *b*.

By taking this groove, say, from the lowest C on an open diapason into the note C, octave above, and by the use of another separate chamber and set of motors, as shown, the open diapason is made to

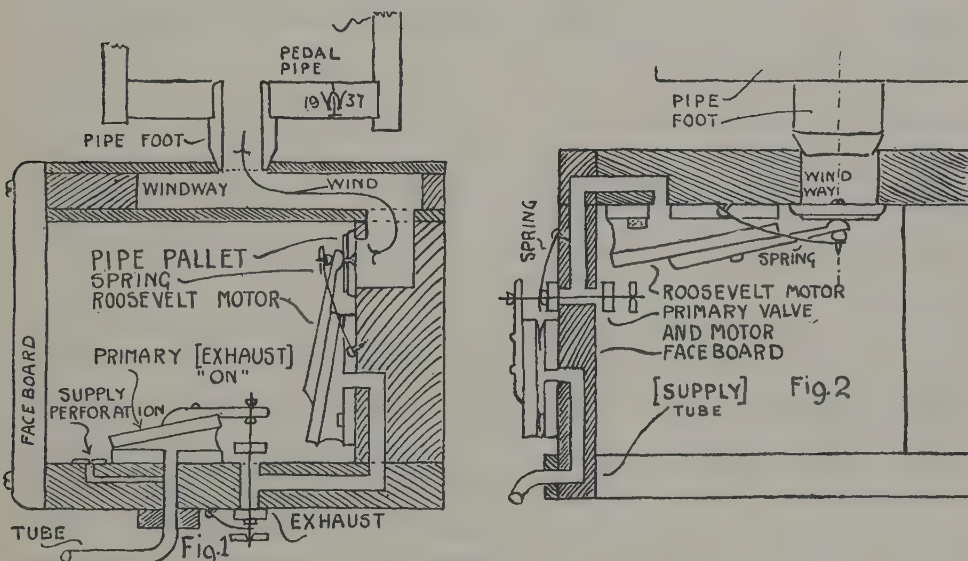


Plate 5

END SECTIONS OF PEDAL SOUND-BOARDS ON THE ROOSEVELT SYSTEM

Fig. 1. Section of a pedal sound-board, exhaust system B^1. Fig. 2. Section of a pedal sound-board, supply system A.

act in the dual capacity of an 8ft. and a 4ft. stop; the octave of pipes omitted at the bottom being added at the top to make up the full register.

Needless to say, beyond the extra octave added at the top, which is voiced as a continuation of the open diapason, no fresh pipes are introduced; therefore, no new tone-quality or timbre, is added. Borrowing in this way is little better than adding an octave coupler.

To the amateur organ-builder, however, the fascination of increasing the resources of his instrument in this way is too great to be resisted, but when carried to excess, it can only result in confusing the player.

By grooving in the upper boards, a bass may also be made to serve for two stops; the one to which it rightly belongs, and to another one which is cut short at the Tenor C.

When a bass is made common to two stops in this manner, they should both be of similar quality of tone, otherwise the result will be more ludicrous than effective.

PLANTING PIPES

"Planting" is the name given to the disposing of the pipes upon a sound-board.

Formerly it was the practice to plant the pipes chromatically, in lessening lengths up to the highest note, beginning at one of the extremes of the sound-board and continuing to the other.

The modern practice is to divide them equally, taking alternate pipes and disposing them upon opposite extremes. This method secures a more equal distribution of the weight of the pipes, a more equal demand upon the wind, and offers greater facilities for tuning. The notes C, D, E, F sharp, G sharp, B flat, are arranged upon one side, with the remainder of the notes, C sharp, D sharp, F, G, A, B, disposed upon the other.

As will be noticed from a glance at some of the diagrams in this volume, the various stops of pipes are disposed from the back to the front of the sound-board, in their order of length.

For instance, we will suppose we have four stops of pipes to plant upon a sound-board; an 8ft. diapason, a 4ft. gemshorn, a $2\frac{2}{3}$ft. twelfth, and a reed, 8ft. The measurements represent the comparative lengths of the lowest pipe C upon each stop.

The diapason should be placed at the back of the sound-board, then the gemshorn, the twelfth next, and the reed at the front.

Reed-stops are always placed upon the front of a sound-board, as they are the ones required to be most frequently tuned. When there are several reed-stops upon one sound-board, they follow the arrangement of the flue pipes, the stop with the longest average length of body being placed at the back. Pipes are therefore arranged in tiers, both in a transverse and a longitudinal direction.

In planting pipes care must be exercised to allow each pipe enough speaking-room. That is to say, there must be so much free space before the embouchure of every pipe. The whole art of planting pipes consists in getting each and every pipe as near as possible directly over its source of supply,* avoiding grooving or conveyancing, and at the same time to allow it ample speaking-room. Pipes placed in a confined area are liable to all manner of eccentricities. They will frequently refuse to sound their fundamental notes, but will, despite the efforts of the voicer, persist in raising to harmonic overtones. Also the resonance is considerably marred, poor, weak tones being the result. It is occasionally noticeable that some stops of pipes, such as a flute stop, made of wood, with their embouchures in close juxtaposition and upon an almost uniform level, will refuse to remain in tune amongst themselves. Frequently, by breaking up the uniform level of the embouchures and putting the pipes upon varying lengths of feet, this difficulty may be overcome.

Sometimes pipes will resound in sympathy with each other. For instance, two open diapasons, placed too closely together upon the same sound-board, will occasionally influence each other. Upon sounding a note in one, a note of similar pitch, or of the pitch of a harmonic, will sound sympathetically in the other.

There are many other cases of acoustical phenomena which might

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* See page 141 for systematic grooving for flue pipes as practised by Henry Willis.

be quoted, all tending to show that economy in this direction is indeed misplaced.

The bass notes of the 8 and 16ft. stops, except, of course, those upon enclosed sound-boards, are generally to be found making up the array of pipes termed the "Front." When this is the case, they are placed upon pneumatic action "off note blocks" (literally small Roosevelt sound-boards), similar to pedal sound-boards. (Note, Plates 2 and 3.) These off note blocks are not necessarily restricted for use in organ fronts, but are used in any position where the basses are taken off the main sound-board. Formerly these off notes were either grooved, or else the wind was conveyed to them through a small metal conduit or "conveyance." Conveyancing and grooving, however, are not favourable methods of accomplishing this object, as the friction the air encounters in the conveyance reduces its pressure; and also, the air requires some time to reach the pipe. In a few isolated instances, this is favourable, but usually, it is the reverse; therefore pneumatic action "off note blocks" are employed.

Another *raison d'être* is that the demand upon the wind in the main sound-board is considerably reduced, often quite twenty per cent. Thus the risk of unsteadiness in the supply is obviated. The objection sometimes urged against this method is that it is apt to produce irregularity of tone in the stops in which it is practised. As it is confined to the lowest octave upon the manuals, and the irregularity, *if any exist*, is only apparent at close quarters, this objection is bordering upon the extreme.

The tube for supplying the off note action is taken from the main sound-board. It has a diameter of about a quarter of an inch, as against seven-eighths of an inch or more if it had been conveyed, so the saving of wind is considerable upon each individual note.

CHAPTER III

BUILDING FRAME, BELLOWS; FEEDERS AND CONTROLLING VALVES OF THE SAME, ETC.

Building frame—Bellows—Leverage of the ribs—Springs on bellows—Single and double rise bellows with inverted folds—The counterbalance—Bellows without ribs—Feeders, hinged and "square drop" varieties—Feeder valves—First class organ building—Long wind trunks—Size of feeders—Test for sufficiency of capacity of bellows—Upon the construction of bellows and feeders—Measuring wind pressures—A scheme of wind pressures—Cut-off valves—Waste pallets.

BUILDING FRAME

THE first part of an organ to be erected is the building frame. It forms the skeleton upon which the anatomy of the organ is disposed. A substantial, solidly made building frame augurs well for the soundness of constitution of the rest of the instrument.

BELLOWS AND FEEDERS

The ideal bellows is one which is capable of supplying a copious and steady supply of wind, equal to all demands, and at an unvarying pressure. Like most ideals, however, it is seldom realised.

Until comparatively recent years, the form of bellows in universal use was upon similar lines to the one shown upon Plate 6. As will be noticed, the bellows consists of one pair of ribs, which form an angle together of about eighty degrees.

For the main bellows of an organ, that is, the bellows into which

the feeders directly communicate, this type of bellows is still frequently used. On account of its peculiarities of structure, however, immediately any sudden demand is made upon the wind it contains, the pressure of the latter is increased. Why this is so, is easily made apparent.

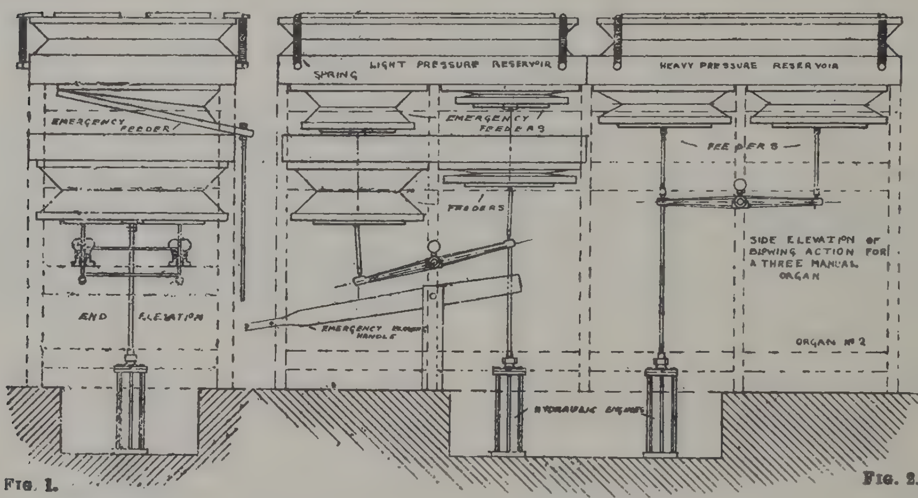

FIG. 1. FIG. 2.

Plate 6

FEEDERS AND BELLOWS, ACTUATED BY TWO HYDRAULIC ENGINES [*Organ No. 2*]

Fig. 1. End elevation. Fig. 2. Side elevation

When collapsed, the ribs of the bellows form together an angle of perhaps ten degrees. At this stage, any air that may be pumped into it has to take the entire weight of the top. Immediately, however, the bellows begins to lift, the leverage of the ribs has to be taken into account. A little consideration will show that as they approach more and more to a right angle, they obtain a corresponding increase in leverage, and, if they were allowed to open until perpendicular, they would support the top unaided.

Although prevented from opening to this extent, the leverage they exert relieves the burden the enclosed air would otherwise have to support in no small degree, thus decreasing the pressure. Upon the

example shown, the reader will notice four spiral springs, connected to the bellows top at one end and to the well at the other. The pull these springs exert upon the top augments as the latter rises more and more, thus counteracting, to a certain extent, the leverage of the ribs. If springs could be adjusted nicely enough to exactly counteract this leverage, all would be well, but unfortunately their adjustment is largely a matter of chance. All single rise bellows, as they are termed, are therefore *liable* to considerable fluctuations in pressure.

As will be imagined, this form of bellows is unsuitable for supplying pipes; its use is, therefore, restricted to main bellows where variations in pressure are of no great moment.

The bellows shown upon Plate 7 is another example of the axiom, "Necessity is the mother of invention." It is designed especially to counteract the above-mentioned defect, and was first introduced in a practical form by one Flight, an Englishman, many years ago.*

It is termed a double-rise inverted folds bellows. The upper pair of ribs, it will be noticed, are separated from the lower pair by a wooden frame, called a rising frame, to which both the upper and lower pair of ribs are attached. As the bellows is inflated, this rising frame is retained midway between the bellows top and the well by the little device lettered upon the drawing "Counterbalance."

The upper pair of ribs is pointing in the opposite direction to the lower pair. If we imagine them (the former) forming the sides of a bellows alone, we shall see that, contrary to the behaviour of the lower pair, they tend to *compress* the air in the bellows as the latter rises. When combined suitably together, therefore, as shown upon Plate 7, their forces are, as Newton has it, "equal and opposite," with the result that the air in the bellows remains at an unvarying pressure, no matter to what extent the bellows is deflated.

There are at present made, bellows entirely without ribs, but the

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* See Appendix

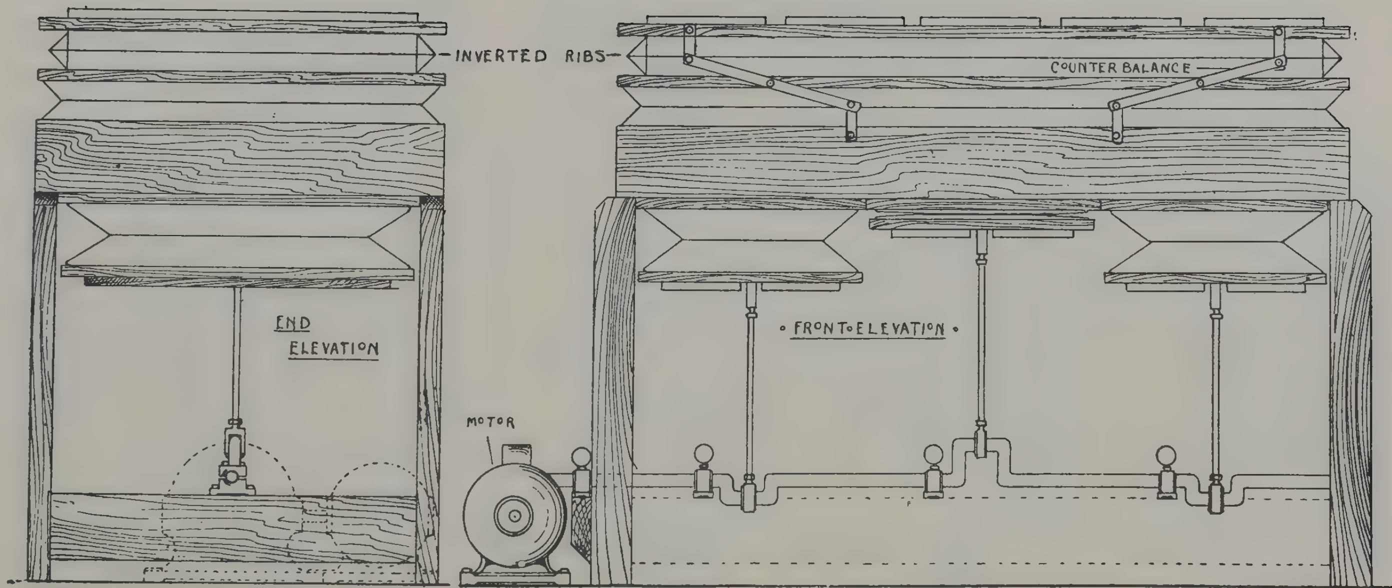

FIG. 1

FIG. 2

Plate 7

END AND FRONT ELEVATION OF BLOWING ACTION ACTUATED BY ELECTRIC MOTOR

Fig. 1. End elevation. Fig. 2. Front elevation

results are not so satisfactory as those obtained from the orthodox kind. This style, it is interesting to note, is a revival of the first form of bellows used.

FEEDERS

Perhaps no part of an organ has been so insensible to change as have the small bellows used to collect and compress the air supplied to the "main." Very little difference exists between them and the forms devised hundreds of years ago to fulfil the same purpose.

There are two varieties in common use at the present time, termed respectively the "hinged" and the "square-drop" feeder. The hinged feeder is the earliest type, and is an almost exact replica of the small bellows used to blow the fire upon the domestic hearth. As will be gathered from an inspection of the end and the longitudinal elevation upon Plate 6, they differ from the square-drop feeders, inasmuch as the name implies, they are hinged at one end, the other being free to move up and down. The square-drop feeder, it will be noticed, opens to an equal extent upon its four sides. Roughly speaking, the hinged feeder has but half the capacity of the square one for the same superficial area of the top. Also, the hinged feeder has a certain amount of leverage over the air it compresses; this latter fact being one of the reasons it is favoured in hand-blowing installations.*

The valves used to retain the air in both feeders and bellows are of a very simple form, literally consisting of a flap of soft leather covering a hole.† In this, as in everything else pertaining to organ work, a whole chapter might be devoted to the subject, so diverse are

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* At one time great use was made, in small organs, of the cuckoo feeder. The name does not serve to enlighten one, but if we imagine two ordinary hinged feeders placed end to end, with their tops as one, so that on one being closed the other is opened, we shall have a clear idea of what a cuckoo feeder is like.

† More correctly, a series of holes, in groups of five or more, not less than one inch in diameter.

the forms in use; but it is of such minor importance that a bare mention will suffice.

A cardinal point in first-class organ building is to have a separate bellows for at least each manual sound-board. This is the case in the organ represented upon Plate 8. It will be noticed that the reservoirs are kept as close as possible to the sound-boards, thus obviating long wind conduits, or, in organ building phraseology, long wind trunks.

Long wind trunks, it may be mentioned here, tend to reduce the pressure and to make unsteady the supply of air.

A fair average amount to allow when calculating the size of any bellows, is from two to three feet superficial area for each stop throughout the instrument. In organ building, however, arithmetical calculations are at a discount, experience being the only safe guide, as the requirements and conditions vary in every case. In this matter it is better, if any doubt exists, to err on the side of liberality, as it is impossible to have a bellows too large. On the other hand, a bellows too small is one of the worst, and one of the most often met with, defects in an organ. It should not be possible, by playing any musical composition, to "play out" the wind, but it is not every organ that can successfully withstand this test.*

NOTES UPON CONSTRUCTION OF BELLOWS AND FEEDERS

All bellows and feeders should have framed and panelled tops, the panels to be easily removable for easy access to the interior valves and pallets.

They should be constructed throughout of substantial timber, to be painted where exposed outside, the inside to be thoroughly sized.

Feeders should work freely and noiselessly.

* In respect of "playing out the wind," it must be remembered that no amount of bellows area will prevent this if feeders, or other blowing machinery, are inadequate. A sufficient area will ensure steadiness, and hold the reserve to meet sudden heavy demands.

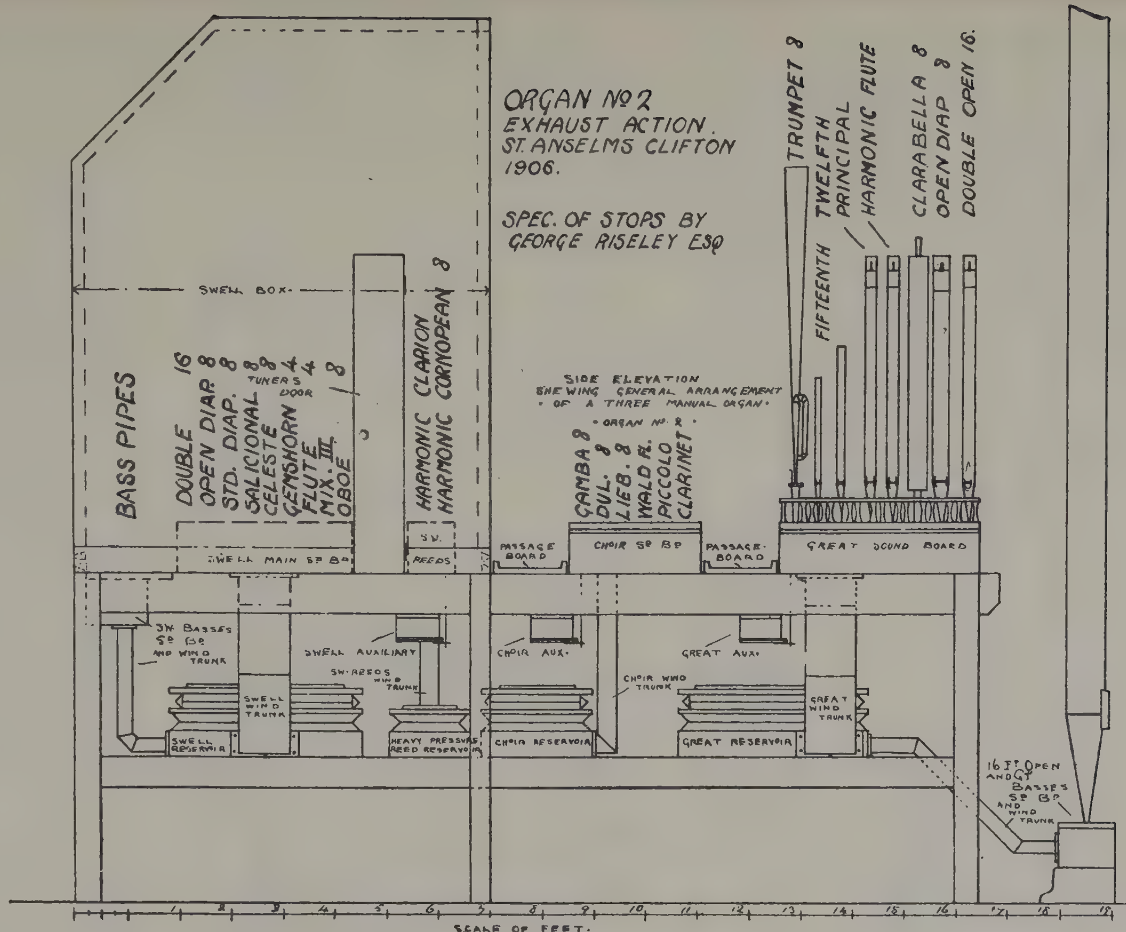

Plate 8

SIDE ELEVATION SHOWING THE GENERAL ARRANGEMENT OF A THREE MANUAL ORGAN. [*Organ No. 2.*]

Where weights are used to obtain the pressure, they should be of metal only, of uniform weight and of portable size. Huge pieces of stone, lumps of scrap iron, old bricks, etc., are sometimes seen serving in this capacity. Under any circumstances, such miscellaneous collections of rubbish should never be used, as, apart from their hideous appearance, they unduly strain the bellows top.

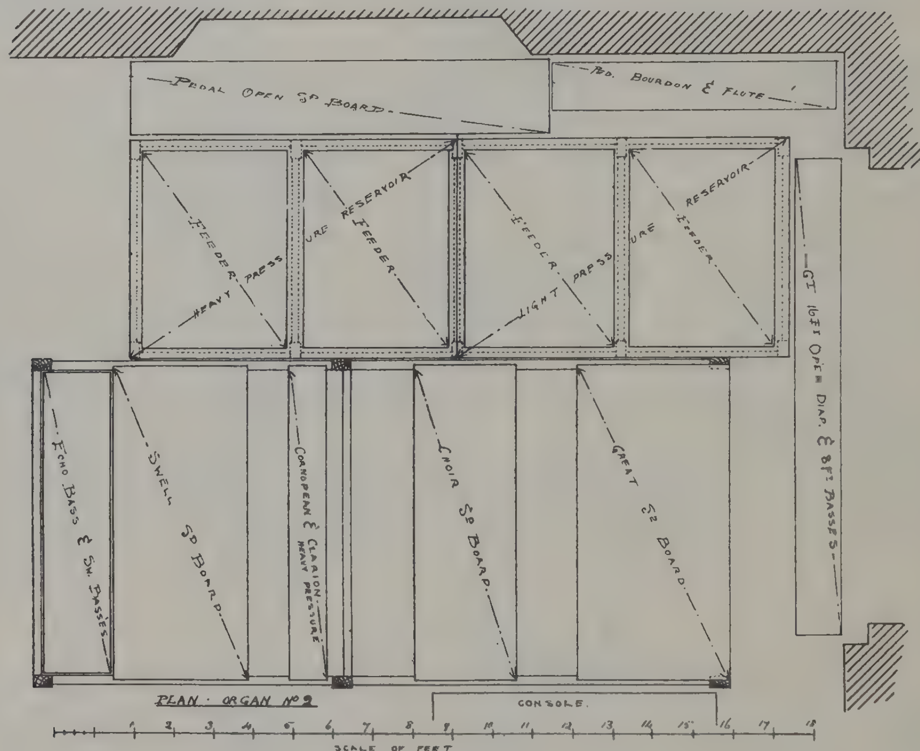

Plate 9

PLAN OF THE ORGAN SHOWN ON PLATE 8

HOW TO MEASURE WIND PRESSURES

The weight or pressure of the wind in an organ is measured by means of the siphon manometer. This is a little instrument consisting of a U-shaped glass tube, whose arms are straight and parallel. One

arm is open to the atmospheric pressure, the other communicating with the air it is desired to measure.

The tube is partially filled with water, which, at atmospheric pressure, remains at a common level in both arms of the siphon. Upon the air under pressure being admitted, the water is depressed in one arm of the tube, rising in a corresponding degree upon the other, the difference of level between the water in the two arms giving the pressure of the air over and above the ordinary atmospheric pressure. Four inches of pressure would mean, therefore, a difference in level of four inches between the two columns of water.

It is impossible to enumerate all the details which, collectively, go to make up the art and science of organ building, but the diligent reader will learn much from a careful study of the various drawings published throughout the work.

Before proceeding further, perhaps it will be well to state with regard to the illustrations that they are all drawn to scale, and most of them specially for this volume. Those lettered in italics, "Organ No 1," when suitably combined, form the instrument shown in end elevation upon Plate 41. Whilst those lettered "Organ No. 2," when combined as shown in the elevations and plan upon Plates 6, 8 and 9, form the "over all" drawing of a three manual instrument. By these means the parts may be studied separately, and again in their relation to each other as a whole. Those without any reference either to Organ No. 1 or Organ No. 2, have been introduced to explain further varieties of mechanism not possible to include as parts of Organs No. 1 or 2.

By enlarging these actual working drawings to full size, an amateur organ builder should find very little difficulty in constructing an instrument similar (or with modification) to the one on Plate 41. That is, an amateur with a fair knowledge of organ building. It is chiefly through lack of working drawings that such attempts too often result in dismal failures; for anyone but a professional and experienced organ builder to attempt to set out an instrument is to invite failure.

The Plates 6, 8, 9, are the elevations and plan of one instrument. It is a typical example of up-to-date organ building, so the following data concerning it may be of interest.

The two main reservoirs, it will be noticed from the plan, are situated at the back. One holds the wind destined for the pipes, the other the wind for the action. They are termed respectively the heavy wind and light wind reservoirs. The following is the scheme of pressures:

Mains	Heavy pressure reservoir	6½	inches
	Light ,, ,,	5	,,
	Swell organ ,,	3¼	,,
	Swell reeds ,,	6	,,
	Great organ ,,	3½	,,
	Choir organ ,,	3	,,
	Pedal open diapason sound-board	5	,,

The large scaled reeds in the swell are placed upon a separate sound-board with a pressure of six inches, the wind for the purpose being supplied from the heavy pressure reservoir, after being reduced the half of an inch in a small bellows for the purpose.

The rest of the manual reservoirs are supplied from the light pressure.

With the exception of the open diapason, the pedal sound-board is supplied from the great reservoir, the capacity of which has been proportionately increased. The pedal open diapason 16ft. is supplied from the light pressure main.

We may note, here, while upon the subject of bellows, that the pressure of wind in a reservoir cannot, obviously, rise *above* that of its source of supply, although it may be reduced to any desired extent. Practically speaking, it cannot equal the pressure of the supply, as the wind loses a little in transit. The main reservoir of an organ, therefore, must be weighted to a pressure a little in excess of that desired from the heaviest reservoir supplied from it.

CUT-OFF VALVES

When air is forced into a reservoir, either directly from feeders, or from another bellows, a point will ultimately be reached at which it can conveniently hold no more.

If the supply is not automatically cut off at this point, and providing the pumping machinery is powerful enough, the bellows will be at first strained and then burst.

To obviate this, a number of devices have from time to time been evolved. We have selected one, shown upon Plate 10, Fig. 1, and termed the equilibrium valve, as being, perhaps, the most improved and up-to-date form.

It consists of two pallets, one attached entirely upon the end of the lever *A*, the other, being hinged at *B*, is allowed to open like a door as the lever *AA* is depressed.

As the air is supplied underneath the valve, and has to pass through it before it can enter the reservoir, it follows that the end of the lever *AA* being attached to the top of the reservoir, as the top of the latter rises it cuts off its source of supply.

There is no strain upon the valve, as its first appearance seems to indicate; there is always a slight amount of leakage from the best constructed of reservoirs,* therefore the valve is never strained tightly closed. Moreover, as the two pallets are equal in area, owing to the construction of the valve, the pressure upon one pallet neutralises that upon the other, the whole arrangement being, as indicated by the name, in a state of equilibrium.

Upon Plate 10, Fig. 2, underneath the cut-off valve, is shown a waste or safety pallet. The type shown is suitable for use in a bellows supplied from a power installation. In the event of the bellows becoming too full of air, the pallet is pulled open by means of the

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* This is not happily expressed. Leakage occurs from organs, even of the best make, not obviously, but none the less surely. Such leakage ultimately tells upon reservoirs which have to maintain the supply by actuating equilibrium, roller, or other main valves.

webbing which is attached to the bottom of the bellows, so permitting the escape of the superfluous air.

In cases where the organ is blown by hand, it is preferable to use one waste pallet for each feeder.

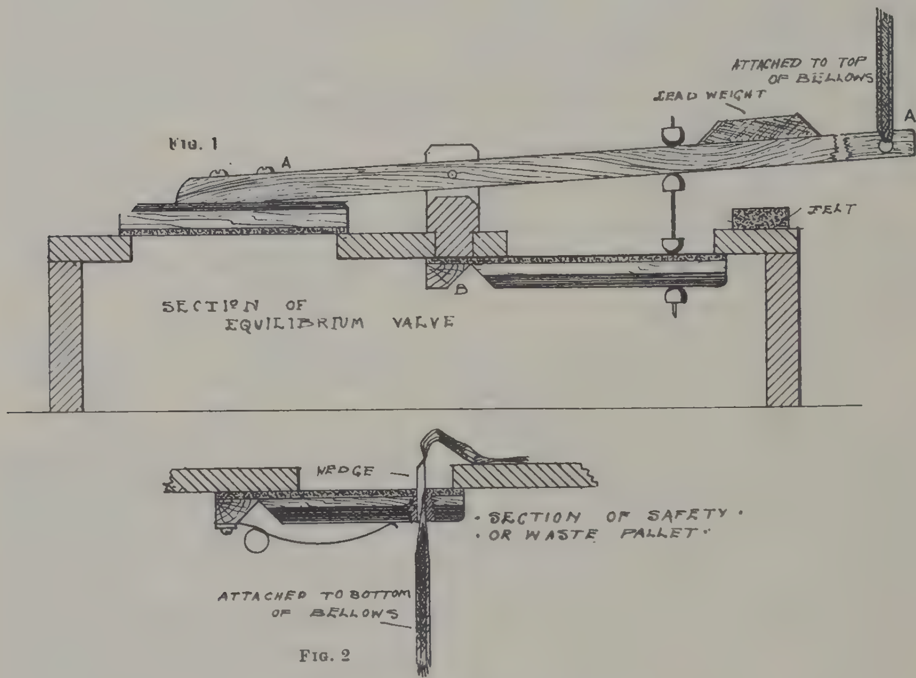


Plate 10

SECTIONS OF AN EQUILIBRIUM VALVE *(Fig. 1)* AND A WASTE PALLET *(Fig. 2)*

With the usual hand-lever blowing action, two feeders are generally employed, so in this case two waste-pallets are requisite, placed inside and upon the bottom of the bellows, communicating when open with the feeders. The tapes to open these pallets should pass out through holes in the bellows-top so that they are adjustable by means of tapering pegs which can be driven into the holes, thereby securing the tapes firmly, first allowing them to be pulled through to the correct length.

When the bellows-top rises above a certain height fixed by the

length of tape attached to the waste-pallets, these are pulled open, and the superfluous air escapes into whichever feeder is ready to receive it. By this arrangement, when the feeders are of equal capacity, in one up or one down stroke of the hand-lever as much air is abstracted from the bellows as is forced into it. When the feeders are of unequal size the same result is effected by *(a)* one movement, when the lever is lifted up and *(b)* two movements, when the lever is brought down and lifted up again. When the feeders are of unequal size, it is obvious that one feeder will pump into the bellows more air than the other will abstract in one movement of the lever, but the surplus will pass out when the lever has been moved twice. In either case, whether the feeders are equal or unequal, the bellows cannot burst through overblowing taking place, if the tapes which connect the waste-pallets to the bellows top are adjusted correctly by experiment.

Where more than two feeders are used to pump air into the bellows, as with an eccentric movement, which is generally made to work three feeders, the extra feeder must be fitted with another waste-pallet. One waste-pallet for each feeder is the rule with this particular way of countering overblowing.

CHAPTER IV

ACTION-WORK *

Draw-stop machines—The ventil—Auxiliary machines—Relay machine—Pedal actions—Key actions and couplers—Manual to pedal couplers—Draw-rod and stop-key actions—Composition actions, mechanical and pneumatic—Pistons—Poppet pedals

DRAW-STOP MACHINES

PLATE 11 shows a pneumatic, slide sound-board, draw-stop action, on the exhaust system.

The main portion is a frame, divided into compartments, one for each slide on the sound-board. This frame is cut into halves. By stretching a piece of leather over each of the compartments, dividing them into two, a membrane is formed. By introducing compressed air to one side, this membrane is forced over in the required direction, and being connected to the slide, takes this with it. On the air being taken in at the opposite side, the membrane is reversed. The working in detail is as follows: the auxiliary motor *A*, being exhausted through the tube by pulling the draw knob on, collapses and reverses the double-acting pallet *B*. This pallet exhausts the motor *B*, which, in turn, reversing the double pallet 1 and 2, allows the air from the chamber *EF*, to rush through the groove *D*, and so on up one side of the membrane. Simultaneously with the entrance of the air into groove *D*, part of it finds its way into the cross-boring *I*, which enters

* The key to this section will be found in that part of the Introduction (page 11) dealing with Action-work.

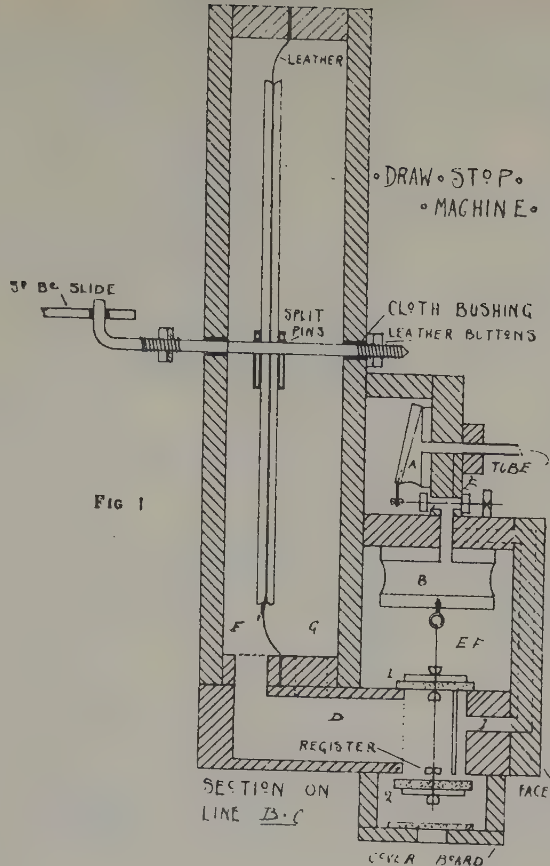


Fig 1

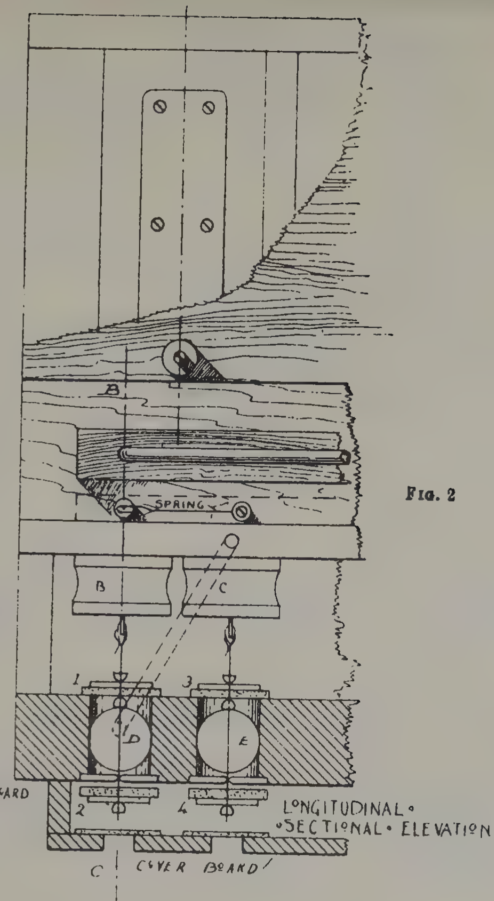


Fig. 2

Plate 11

DETAILS OF A DRAW-STOP MACHINE—THE MECHANISM THAT ACTUATES THE SLIDES IN A PNEUMATIC ORGAN EXHAUST SYSTEM B[1]

Fig. 1. Section on line BC. Fig. 2. Longitudinal elevation

NOTE.—This drawing was originally intended for use in the workshop. The motor C, will, under pressure, automatically assume an opposite position to motor B.

a motor *C*, directly behind the motor *B* (see elevation, Plate 11, Fig. 2). The motor *C* is similar to the motor *B*, having control of a double-acting valve over the groove *E*. As a little consideration will show, the motor *C* will always be in direct opposition to the motor *B*, so that, as one supplies air to one side of the membrane, the other motor will be exhausting it from the other, and vice versa.

On the draw-knob being put in, the auxiliary motor *A* is supplied with air, and returns to the position shown, the other motors and valves following suit. The membrane is now supplied with air from the groove *E* (sectional elevation, Fig. 2) the air in the other side exhausting via the groove *D*, and so out at the pallet 2.

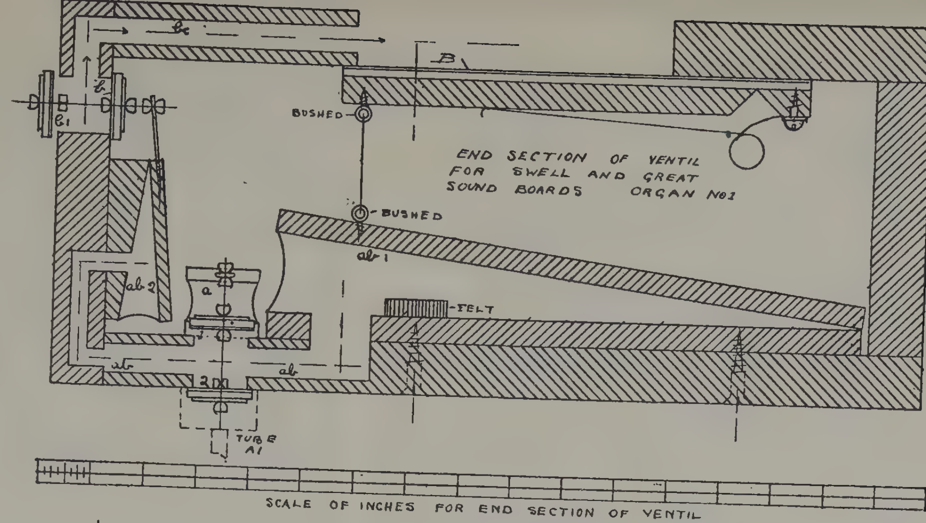
Some builders substitute large motors in place of the membrane, one being to pull the slide out and the other to return it. Others, again, use only one motor acting against a spring. When the motor is supplied with air it pulls the slide on; and when exhausted of air, the spring closes it, so returning the slide.

THE VENTIL

Ventil is the name given to a large pallet controlling the supplying and exhausting of air from a wind chest, usually a sound-board. The ventil shown on Plate 12 is designed for the Roosevelt sound-board on Plate 3. It takes the place of the draw-stop action by supplying the wind chambers with air when the stop knob is drawn. The action is as follows:

The auxiliary motor *a*, Plate 12, Fig. 1, being exhausted through tube *a*1 by pulling out the draw-knob, reverses the double-acting pallet 1 and 2. The groove *ab* now being open to the outside atmosphere, the pressure inside the ventil collapses the motors *ab* 1 and *ab* 2. These motors being connected to the pallets *B* and *b*, pull them open, and the air escapes from the ventil through the main pallet *B*, and the smaller pallet *b*, into the sound-board. So long as the draw-knob is on, the large pallet remains open to its full extent. On pushing it in,

Fig. 1



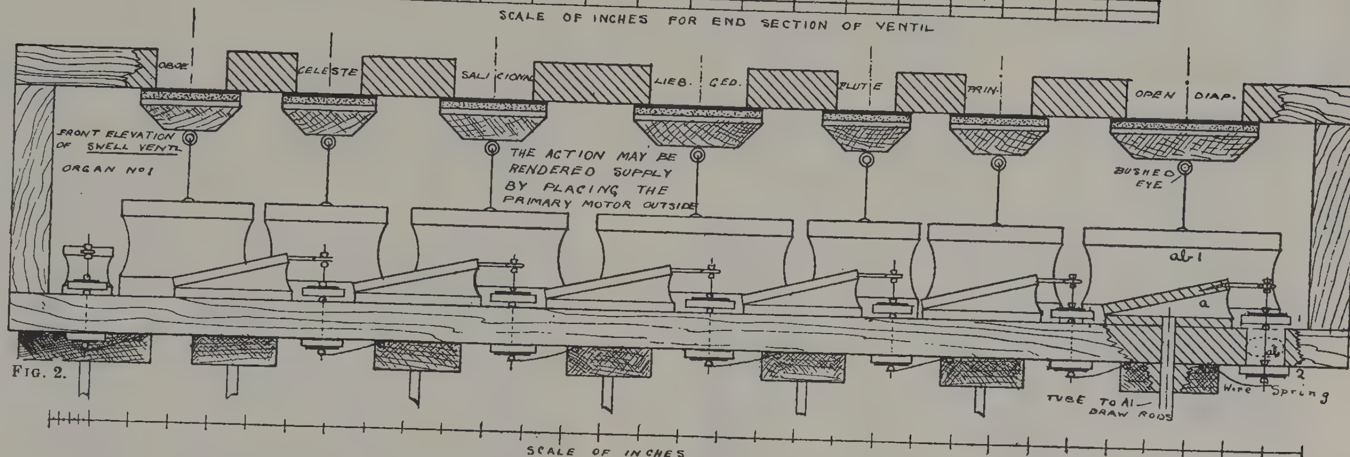


Fig. 2.

Plate 12

DETAILS OF A VENTIL FOR CONTROLLING THE STOPS ON A ROOSEVELT CHEST [*Organ No. 1.*] **EXHAUST SYSTEM B**

Fig. 1. End section. Fig. 2. Front view with faceboard removed

the auxiliary motor *a*, regains the position shown in the drawing, so causing the other motors to follow suit. The main pallet *B* is now closed, cutting off the supply of air into the sound-board; the residuum of air left inside is exhausted through the pallet *b*1.

If the action of the ventil is required to be supply, the auxiliary motors should be placed outside the ventil, the other particulars remaining the same.

If the ventil (Plate 12, Fig. 1) was intended for supplying a pedal sound-board, the trunk for conveying the wind away would go over the main pallet hole. The trunk bringing the supply of air from the bellows would come, wherever convenient, into the box part of the ventil. Whatever the purpose of the ventil, the supply trunk would, of course, always come into the under side of the main pallet.

In case any of our readers desire to make the ventil, in connection with Organ No. 1, the front view is shown, Plate 12, Fig. 2.

AUXILIARY MACHINES

The name auxiliary machine or auxiliary action is given to that particular pneumatic action designed to open sound-board pallets controlling pipes, the pressure of air on these pallets assisted by a spring returns them closed, when the auxiliary action releases its pull in response to control.

Unless under special circumstances, a semi-separate or separate auxiliary machine is not used with pedal sound-boards, but some of the examples given under this heading may be adapted for pedal work. In the usual way auxiliaries for pedal sound-boards are made as parts of these sound-boards.

For manual work, auxiliary machines may be made as part of the sound-board, or they may be semi-separate, or entirely separate. If semi-separate, one motor is placed upon the bottom board and connected to the pipe pallet. (One motor for each pallet, of course; for convenience of description we deal only with the action necessary for

one note.) In this case, the remainder of the machine would be made to fix in position underneath the sound-board. If entirely separate, the machine may be supplied with air of greater pressure than that necessary for the pipes; thus we have the distinction, pipe wind and action wind.

Apart from modifications of design corresponding to the supply and exhaust system, and variations due to the practice of different builders, auxiliary machines may be divided into three kinds. One of these is past, the other two are with us.

For convenience we will label these three:

(1) The primary motor type.

(2) The primary and auxiliary motor type.

(3) The primary, secondary and auxiliary motor type.

No. (1) action can no longer be found in modern organs. The first kind of tubular pneumatic actions were of this description. It is the most simple arrangement possible to devise, and as such we will consider it as helping to explain the necessity for two and three motors in such actions.

(1) The simplest and first kind of tubular "auxiliary"* machine, then, was a single motor supplied and exhausted through a tube which connected it to a valve at the key. This tube replaced the tracker action utilised in the Barker lever, with this difference:

The motor in the Barker lever was placed close to the valve controlling it, the key moving the valve by means of a thin wooden connecting rod, or "sticker." The motor was attached to a tracker action which spanned the intervening distance between motor and sound-board, so motion was communicated to the sound-board pallet through the tracker action when the motor was inflated.

The introduction of a tube replaced the tracker work as a means of communication, not between the motor and the sound-board but between the valve at the key and the motor, which was then placed

* The single motor pneumatic action cannot properly be termed an auxiliary machine, but we retain the words for convenience.

close to the pallet. And there, what we have called in this book the primary motor, has remained ever since.

Even with a tube of large diameter, this action proved too sluggish for its purpose upon ordinary wind pressures, and owing to economical considerations, it is not desirable to obtain efficiency in pneumatic actions solely by employing extraordinary pressures. Consequently this action is obsolete.

(2) This action, the second in the list, was invented to overcome the difficulty presented in the previous paragraph. It consists of two motors—our primary remains unchanged in dimensions proportionate to the sound-board pallet—and we now have a smaller additional motor an auxiliary. As far as concerns the primary the tube is virtually abolished, and it is placed directly in communication with its supply via the double acting pallet attached to the auxiliary motor. The tube now goes into this smaller motor. This may be represented in this way:

Sound-board pallet (controlling the admission of air to speaking pipes).
(1) Primary motor (actuating sound-board pallet).
Double acting pallet (controlling the primary motor).
(2) Auxiliary motor (actuating the double pallet).
Tube (an extension of the air inlet and outlet of the auxiliary motor).

By adopting this practice it was found that the repetition of the action was accelerated by reason of the tube communicating with a much smaller motor than was originally the case. Being comparatively small, it contained less air, and consequently was "emptied" and "filled" again (other factors remaining constant, such as diameter and length of tube, pressure, etc.) in less time than the primary originally took.

This kind of action is still found effective upon short tubes, and upon longer ones where the dimensions of the primary allow of the auxiliary being reduced sufficiently.

The success of this experiment led to further development of the same idea, and resulted in an action consisting of three motors.

(3) This, the "three motor" action, may be represented thus:

Sound-board pallet.
(1) Primary motor.
Double acting pallet.
(2) Secondary motor.
Double acting pallet.
(3) Auxiliary motor.
Tube.

We have considered the primary motor throughout this explanation as being unchanged in size, as it would be if attached invariably to any definite pallet controlling any definite note. Consequently the motor related to it would be invariable as regards size. Therefore it will be seen that the auxiliary motor of the previous action becomes the secondary one in this action, another and still smaller motor taking the name of auxiliary in this case. The figures further elucidate this point.

By this arrangement of motors, lessening in size unto this last, the auxiliary of the last action, it is found possible to reduce the diameter of tubes, and still, with even moderate wind pressures, to obtain prompt repetition providing long tubes are not used. Long tubes necessarily mean high wind pressures.

A point for consideration with multiple motor actions is, the more motors and valves between the tube and the primary motor, the more time taken in transmitting motion from the first to the last. It is this fact which puts a limit upon the number of motors used in auxiliary machines.

The inside diameters (bores) of tubes used with modern pneumatic actions vary according to style of action, wind pressure available and distance to be traversed. With the exhaust system smaller diameters are possible than with the supply system. Inside diameters of three-

eighths of an inch, five sixteenths to one quarter of an inch are in general use.*

No matter how perfect a pneumatic action may be, regarded as a piece of mechanism—pressure remaining constant, as tubes are lengthened the time interval between the act of depressing a key and movement of the action must become greater. Disregarding friction in tubes entirely, the velocity of air in proportion to pressure is so low,

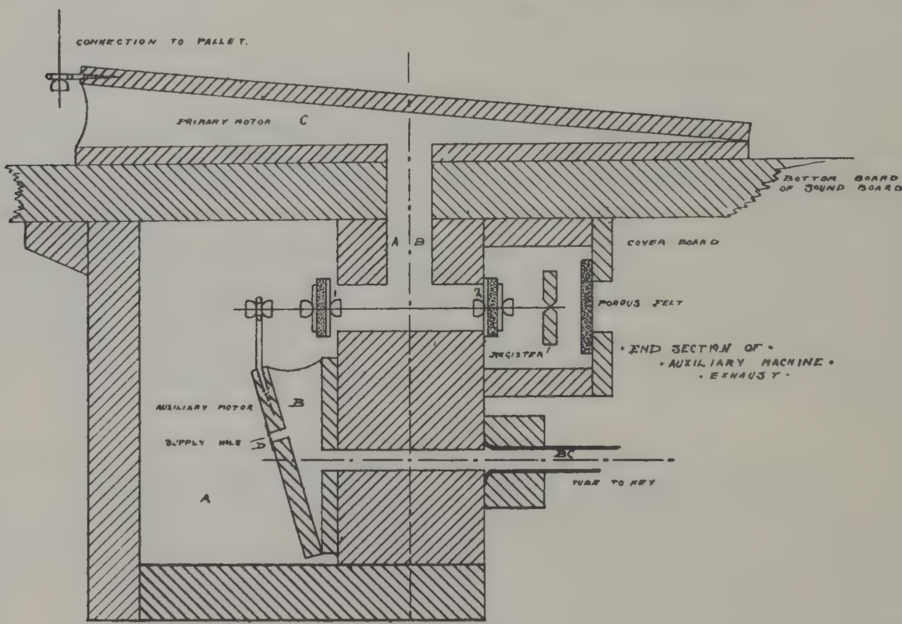


Plate 13

DETAILS OF AN AUXILIARY MACHINE, EXHAUST SYSTEM B[1] (TWO-MOTOR TYPE)

that except with pressure so enormous as to be impractical for organ building this velocity becomes measurable as a delay when moderate distances are exceeded. It is always the aim of builders to scheme so that long runs of tubes may be avoided as far as possible.

As regards auxiliary machines in particular, and pneumatic action in general, the higher the wind pressure the better, within reasonable

* For main tubes, some builders who use the supply system use bores as large as ½ in.

limits. The chief restriction in this direction are: expense, primarily; and the noisiness of high pressure actions.

In one instance, we know of three motor type auxiliary actions on a pressure of 3ins., working satisfactorily on tubes not longer than 8ft.* On the other hand, a large organ (recently built by the firm of Willis and Sons and Lewis and Co., Ltd.) has pressures of 8in. and 12in. for the action work. In the last instance, tubes are, naturally, much longer than 8ft.

On Plate 13 will be seen one of the most simple forms of pneumatic action now in use. The double acting pallet 1 and 2, takes the place of the small valve described in the Barker lever. The tube *BC* is continued into the key-action, where it is exhausted of air on the key being depressed, the valve 1 and 2 being reversed. The hole at pallet 2 now being open, the pressure on motor *C*, which is in the well or chest of the sound-board, causes it to collapse, so opening the pallet to which it is attached. The key being released, the end of the tube *BC* is covered, allowing the air from chamber *A* to fill up motor *B* through the tiny supply hole *D*. The large motor *C* is supplied through the hole at pallet 1, and regains the position shown. When the action is at rest, a light steel wire spring retains the motor *B* open. This is made necessary by the fact that, in the off position (as shown) the pressure inside and outside the motor *B* is exactly the same, it is, therefore, in a state of equilibrium. In this state, were it not for the steel spring, the additional pressure upon the pallet 1 would retain this closed, that being the opposite to the position desired.

The spring is adjusted by experiment to give the exact tension.

The part lettered "cover board" is intended as a protection against dirt and damage. It is, of course, easily removable. Holes are bored at intervals in this, covered upon the inside with porous material, thus permitting the free escape of the exhaust air.

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* Bore ¼ in.

Unless a higher pressure of air is used than is generally obtainable or desirable, the form of action shown upon Plate 13 will not give a satisfactory repetition upon a tube of greater length than about 6ft.

Plate 15 illustrates a relay machine for exhaust action: by placing the motor on the exterior of the box, it would serve for supply action. Where long tubes between console and organ are unavoidable, this accelerates the impulses passing through the tubes.

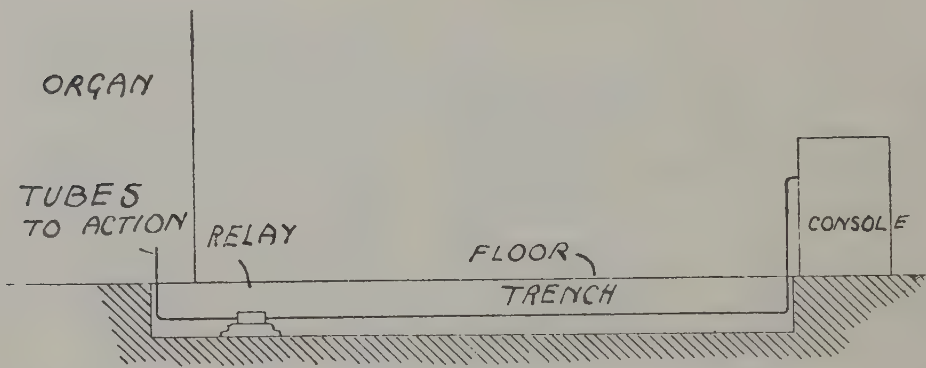

Plate 14
RELAY MACHINE

When a key is depressed the motor is exhausted, reverses the double pallet, and exhausts the tube communicating with it. When a key is released, the motor regains its static position as shown, and supplies the tube from the double pallet. It is placed at some convenient point so that long tubes are about equally divided (see Plate 14).

Where console work is on the exhaust system, and auxiliary machines on the supply system, by turning the motor "right about face," and providing a long arm to connect to the pallet (an important detail) the tube impulses may be suitably reversed.

The action of the drawing on Plate 16 is as follows:

Compressed air being in chambers *AA*, the small supply hole allows the motor *A*1 to be held open by the spring on the double-

acting pallet *A*2 and *A*3, allowing the wind from *A* to go via the groove into the motor *A*2. This motor is held over by the spring *E*1, on the double pallet *B*1 and *B*2, allowing the air from chamber *AA* to go into the primary motor through the groove *ABCD*, thus keeping the sound-board pallet up. (Not shown on the drawing.)

On depressing the key, the auxiliary motor *A*1 is exhausted of air, reversing the double pallet *A*2 and *A*3, and so exhausting the secondary motor *A*2 into the outside atmosphere, via the groove *ABC*. The double pallet, *B*1 and *B*2, is now reversed, and the primary motor

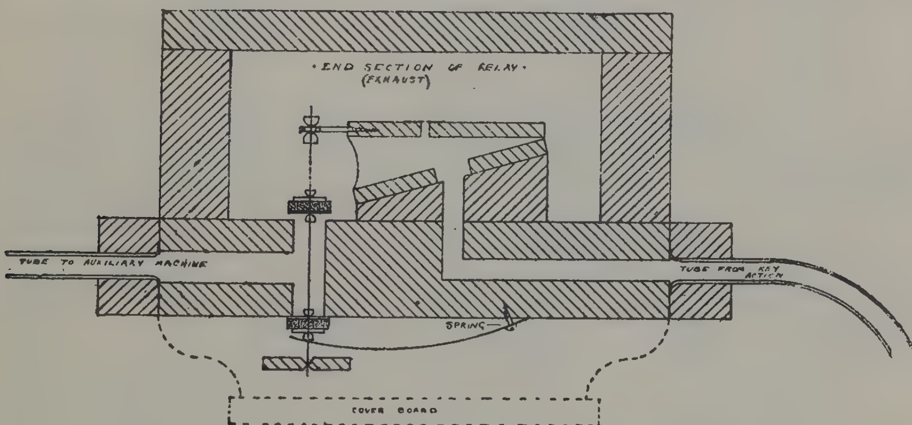

Plate 15

A SIMPLE RELAY MACHINE. EXHAUST SYSTEM B^1

is exhausted through the groove *ABCD* over which it is situated, so pulling the sound-board pallet open. When the key is released the action comes to rest as shown.

A modification of the action on Plate 16 is shown on Plate 17. As shown it is at rest. The auxiliary motor *A* is inflated through the small supply hole, so holding up, with the assistance of the flat spring, the double pallet controlling the secondary motor *AB*. As shown, this motor is attached to the double pallet *CD*, which supplies the primary motor over the groove. (Primary motor not shown.)

On depressing the key, the auxiliary motor *A* is exhausted, pulling down the double pallet to which it is attached, and so supplying

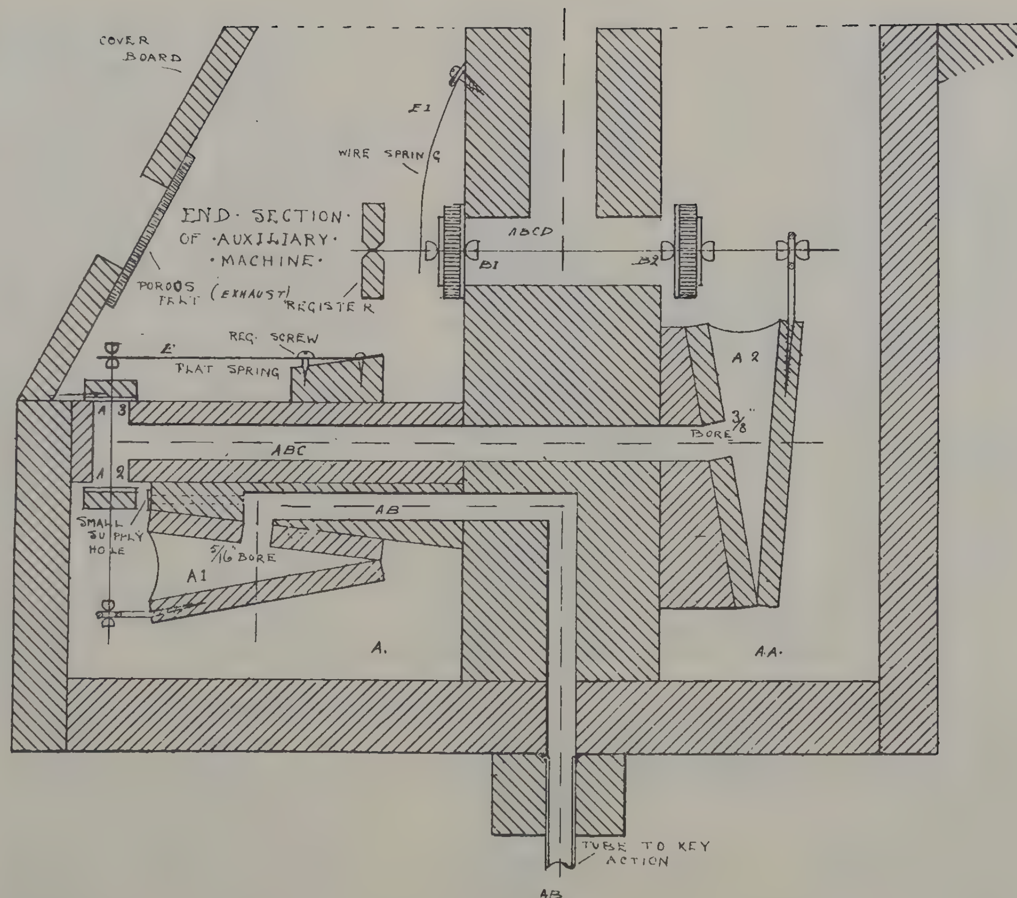

Plate 16

DETAILS OF AN AUXILIARY MACHINE, EXHAUST SYSTEM B^1. (THREE-MOTOR TYPE)

the secondary motor *AB*. This motor is reversed. exhausting the primary motor attached to the pallet, so pulling it open.

No spring is required on the motor *AB*.* The tension of the flat spring on the auxiliary pallet is capable of adjustment by means of the regulating screw shown.

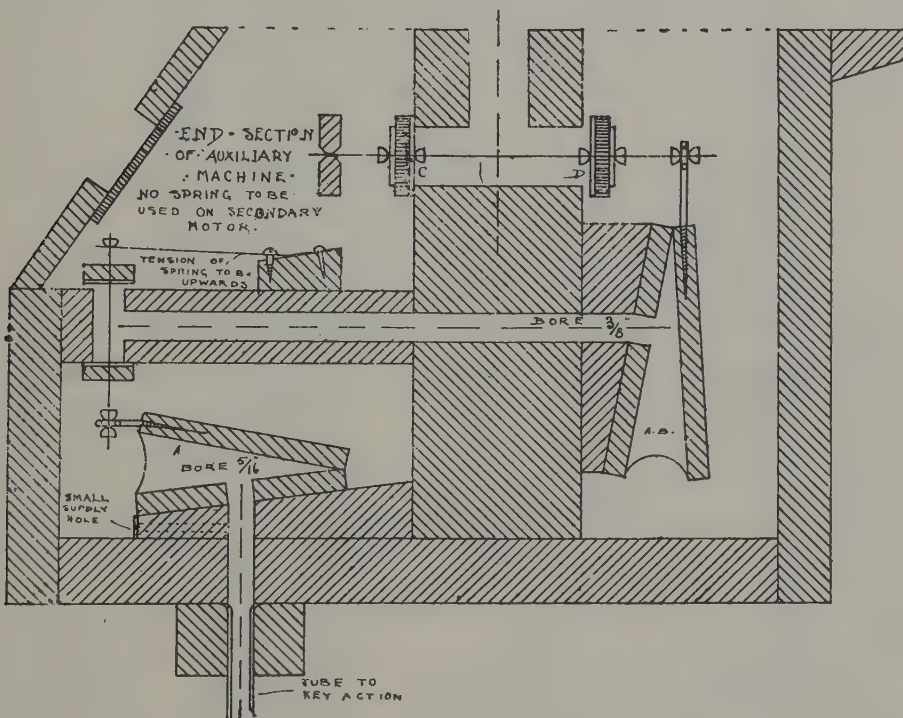

Plate 17

DETAILS OF AN AUXILIARY MACHINE, EXHAUST SYSTEM B[1] (THREE-MOTOR TYPE)

The primary motors for the two actions upon Plates 16 and 17 are fixed upon the bottom board of the sound-board, directly underneath the pallets. These actions are constructed separately from the sound-board itself, being screwed into position when the latter is made.

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* A more perfect result will be obtained from this action if the arm of motor *AB* is the half of an inch longer than the top of that motor, in similar fashion to the method adopted with the motors in the Roosevelt chest.

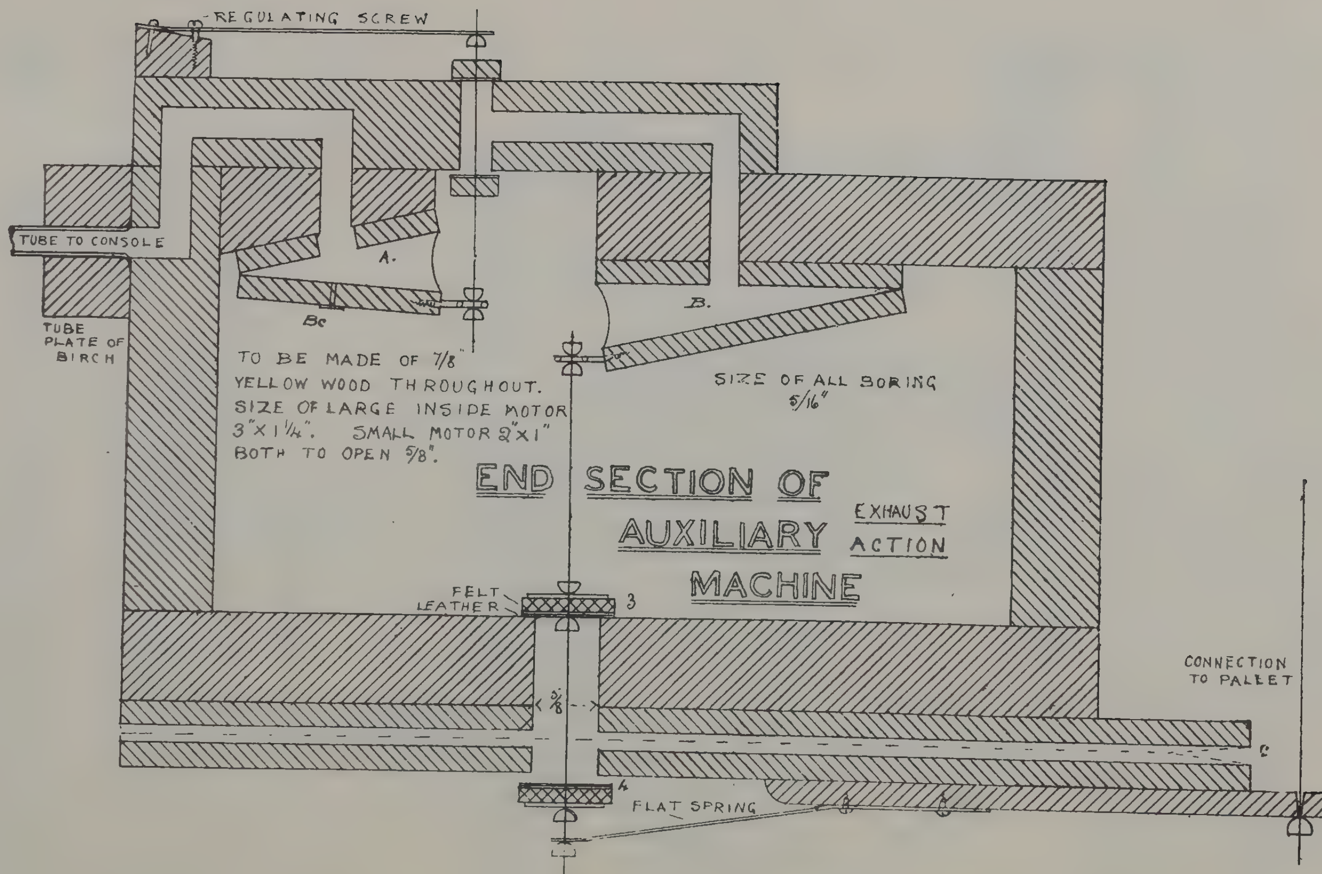


Plate 18

DETAILS OF AUXILIARY MACHINE WITH THE PALLET MOTOR OUTSIDE, EXHAUST SYSTEM B[1]. [*Organ No. 2*]
(THREE-MOTOR TYPE)

A type of action distinctly differing from those previously described is that given on Plate 18. Here the primary motor is outside the box.

On the key being depressed, the auxiliary motor *A* is exhausted, and reverses the double pallet controlling the groove into the secondary motor *B*, which in turn promptly lifts the double pallet supplying the primary motor. This latter, now being supplied with air opens at *C* and so pulls open the pallet in the sound-board. On releasing the key, the cycle of movements is reversed, the auxiliary motor recovering the position shown, being supplied through the hole *Bc*. The other motors being forced to follow suit, the pallet is closed.

The action shown upon Plate 19 differs slightly from those previously shown, inasmuch as it is on the supply system. It is shown in the "on" position for convenience of explanation. Normally, the two membranes *C* and *D* are collapsed, so that, on the tube *ab* being *supplied* with air under pressure, they are distended to the position shown upon the diagram, holding up and down respectively the pallets to which they are attached. In this position, the secondary motor *E* is collapsed, holding up the valve at *F*, and as the pallet at *D* is firmly held down, the primary motor is distended, pulling open the sound-board pallet to which it is attached.

Upon *releasing* the key, the compressed air in the tube *ab* is exhausted, the membrane *C* being collapsed, and the motor *E* is supplied with air from the chamber *A*, cutting off the supply of the primary at the pallet *F*. As the air upon each side of the membrane *D* is now at the same pressure, the compressed air in the primary exhausts by forcing up the valve *D*, and the motor is collapsed.

In the supply system of action, the compressed air enters the tube at the key end, but in the usual system of exhaust action, the contrary is the rule, the air filling up the tube from the auxiliary.

In no pneumatic action is it necessary that the compressed air shall actually travel the entire length of the tube, end to end. The motion is comparable to, and in fact, actually is, wave motion.

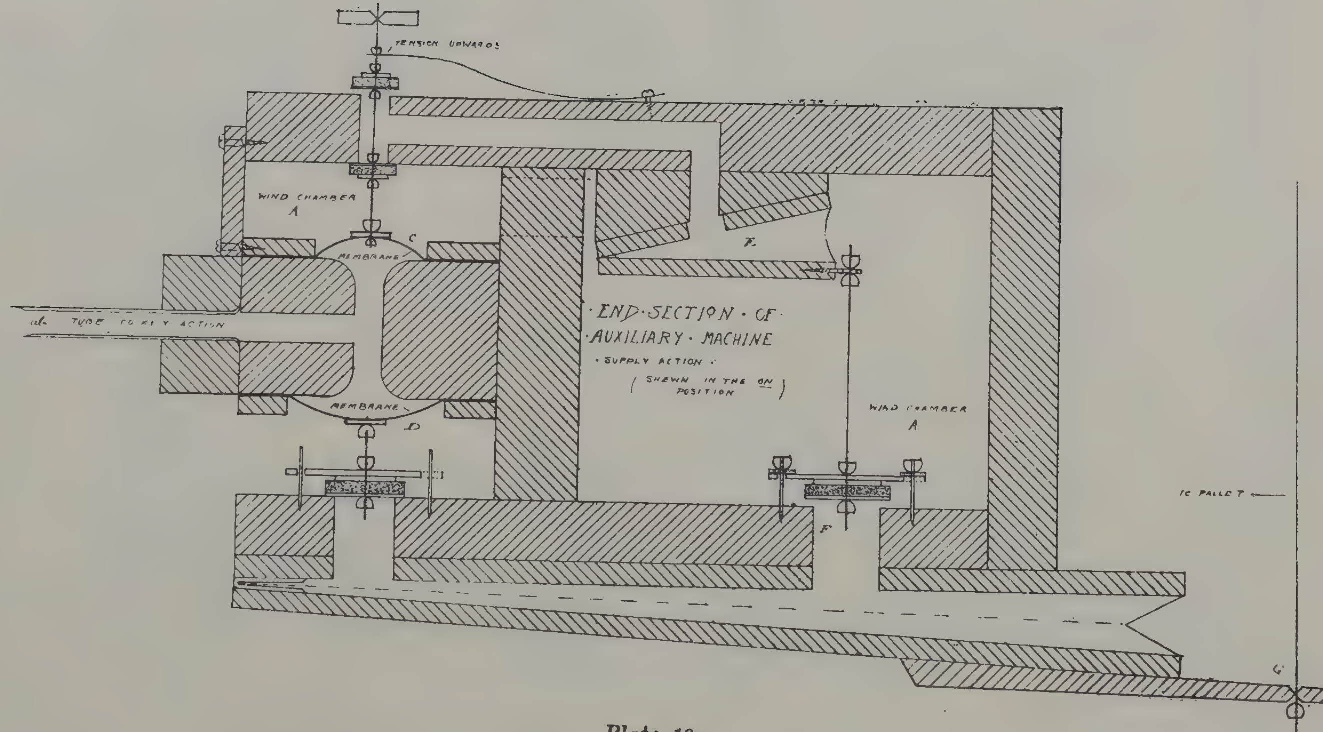


Plate 19

DETAILS OF AN AUXILIARY MACHINE ON THE SUPPLY SYSTEM A. (THREE-MOTOR TYPE)

In the tube of a supply action, upon releasing the key, the air is at atmospheric pressure. In the exhaust system *B* 1, the air in the tube is at all times above atmospheric pressure.

At first sight, it appears from this, that as the air in the tube of the exhaust action is always higher than atmospheric pressure, and consequently occupies less time in getting up to the pressure required to distend the auxiliary motor, the action must be capable of a greater number of repetitions to the minute than the supply system, when both are upon the same length of tube and wind pressure. This is not so, however, for a very simple reason. In the exhaust system, when the tube is supplied from the auxiliary machine, the supply hole is of very small dimensions (about one-thirtieth of an inch), consequently the air cannot pass through very quickly.

If the supply hole is made too large, the action is rendered slow in coming on, if too small, the contrary is the result; so in this as in everything else pertaining to organs, the golden mean is the most satisfactory.

In the supply system, however, the supply hole for the tube is not restricted in this way; it is made of greater diameter than that of the tube; but the gain here is counteracted by the air in the tube having to be raised from atmospheric pressure, up to the pressure required to distend the auxiliary motor. The results from both are, therefore, similar in this respect; but the exhaust system is the most up-to-date, and it certaintly has the desideratum of greatest simplicity, and facilitates the addition of couplers.

KEY AND PEDAL TOUCHES AND COUPLERS

The most simple form of pedal touch, or, as it is more usually called, pedal machine, is shown on Plate 20, Fig. 1. It is simply a pallet, in this case a small lever or jack, which covers the end of the tube or tubes, according to the number of stops. When the jack *A* is

pushed down, by depressing the pedal, it uncovers the end of the tubes *BC*, so allowing the air to discharge through them from the auxiliary motors to which they are taken. This is the exhaust system.

The supply system machine is a trifle more complicated (Plate 20, Fig. 2). The details of construction will be seen on the drawing. On the pedal being depressed, the jack *Aa* is pushed downwards, causing the double pallet 1 and 2 to fall, so supplying the tube *D* with air from the chamber *ABC*. On the pedal being released the jack returns to the position shown, so exhausting the tube.

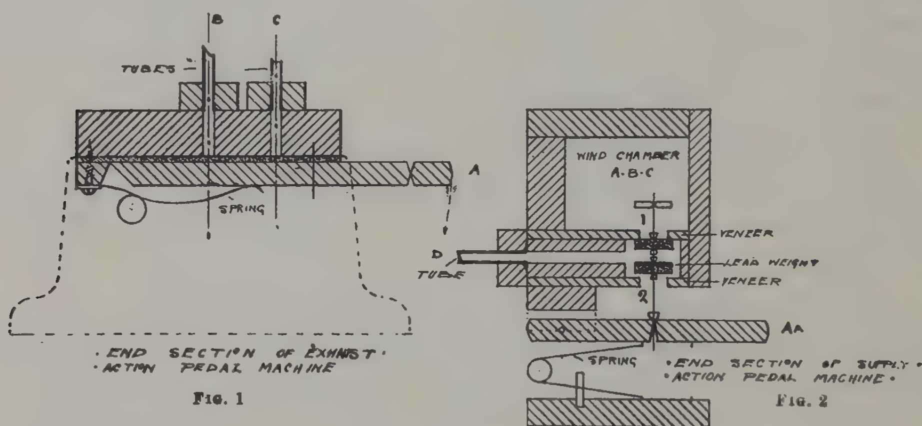


Fig. 1

Fig. 2

Plate 20

SECTIONS OF PEDAL MACHINES ILLUSTRATING THE EXHAUST SYSTEM B[1] *(Fig. 1)* AND SUPPLY SYSTEM A *(Fig. 2)*

The key touches are on exactly the same principle, but appear more complicated on account of their increased parts For the moment we will ignore the couplers, and consider the action by itself.

Depressing the key *A* at the front end (Plate 21), causes it to lift the jack *A*1, from off the tube *BC*, so allowing it (the tube) to exhaust the auxiliary motor into which it is taken. On being released, the pallet on the jack covers the end of the tube *BC*, so rendering it air tight. The screw wires *CD* and *CD*, form a means of adjusting the depth of the touch, i.e., the depth of movement of the key at the front.

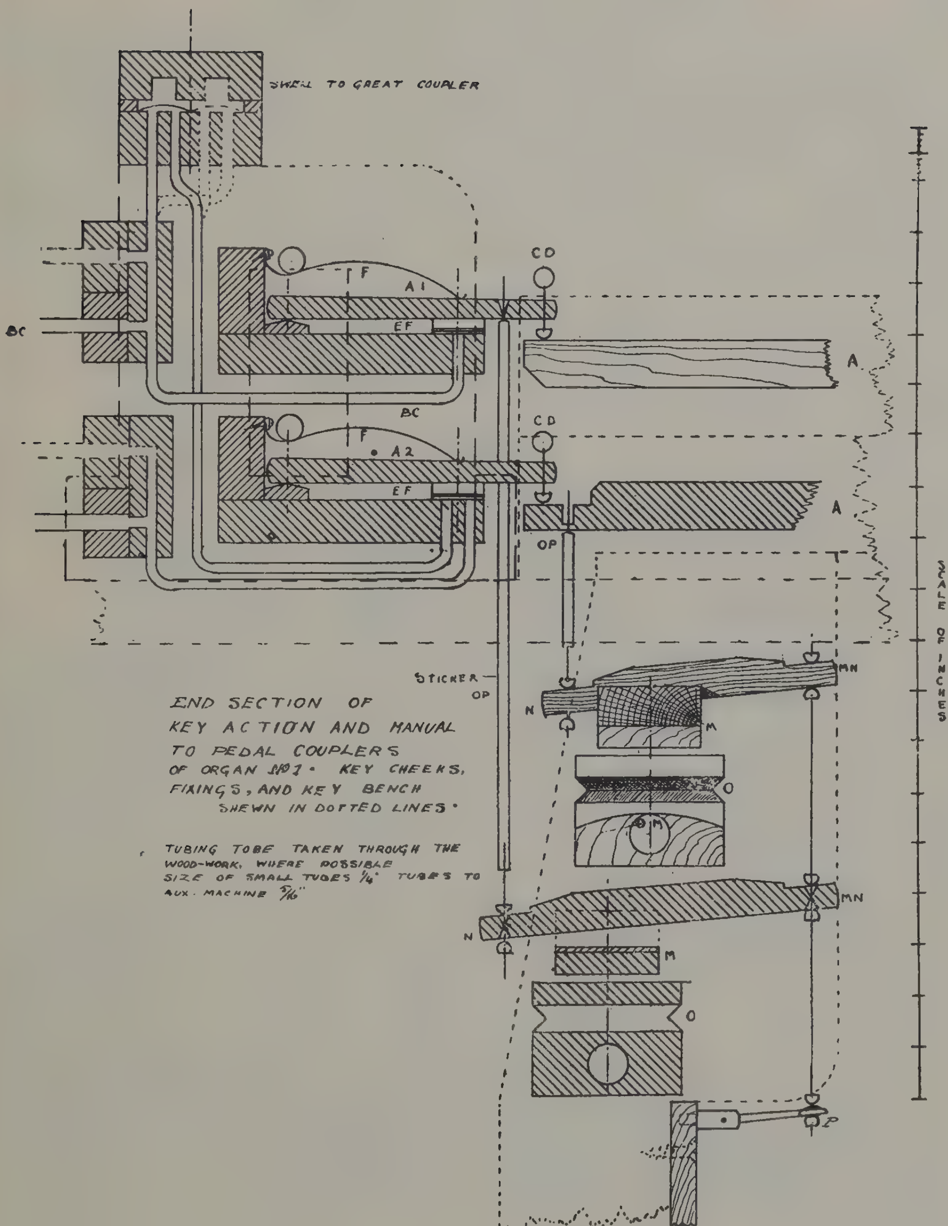


Plate 21

DETAILS OF A CONSOLE SHOWING KEY ACTION AND VARIOUS COUPLERS FOR A TWO MANUAL ORGAN. [*Organ No. 1*] EXHAUST SYSTEM B^1

The springs *FF** hold the pallets firmly down over the tubes, and are tensioned to give a pressure of five ounces at the front of the keys

A part section of the exhaust coupler will be seen on Plate 22. It is made up of three thicknesses of mahogany (Fig. 1). The top piece, in which are cut two square section grooves, the middle piece, in which are bored circular holes, covered on the under side with a film of leather, and the bottom piece, through which the tubes are taken to effect the coupling. A glance at the plan, Fig. 2, will show that the circular holes bored in the thin middle piece, fit exactly over the ends of the pairs of tubes brought through the bottom piece. When the coupler is off the square section grooves *AA*, Fig. 1, are charged with air, and retain the membranes *B* in position over the ends of the tubes *CB*, effectually stopping the passage of air from one tube to the other.

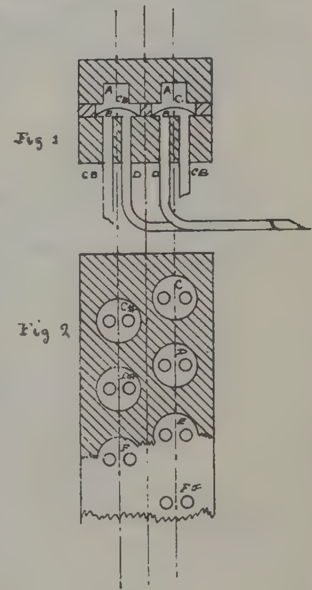


Plate 22

PNEUMATIC COUPLER. EXHAUST SYSTEM B[1]

When the coupler is on, the air is exhausted from the grooves *AA* by a suitable draw-rod action. On the key now being depressed, the air from the auxiliary motor, being at a greater pressure than that in the grooves *AA*, forces up the membrane to the position shown and makes its escape, via the tube *D*, at the pallet on the key movement.

The coupling holes are bored alternately back and front, to economise space. The section, Fig. 1, therefore, represents two notes; we will say bottom C and C sharp as marked. We will suppose the diagram represents a Swell to Great coupler. Taking the bottom note C, the tube *CB*, will run into the bottom *C* tube of the Swell auxiliary machine, the other tube *D* going into the key action, where it

* A leg spring is preferable to the type shown on the drawing.

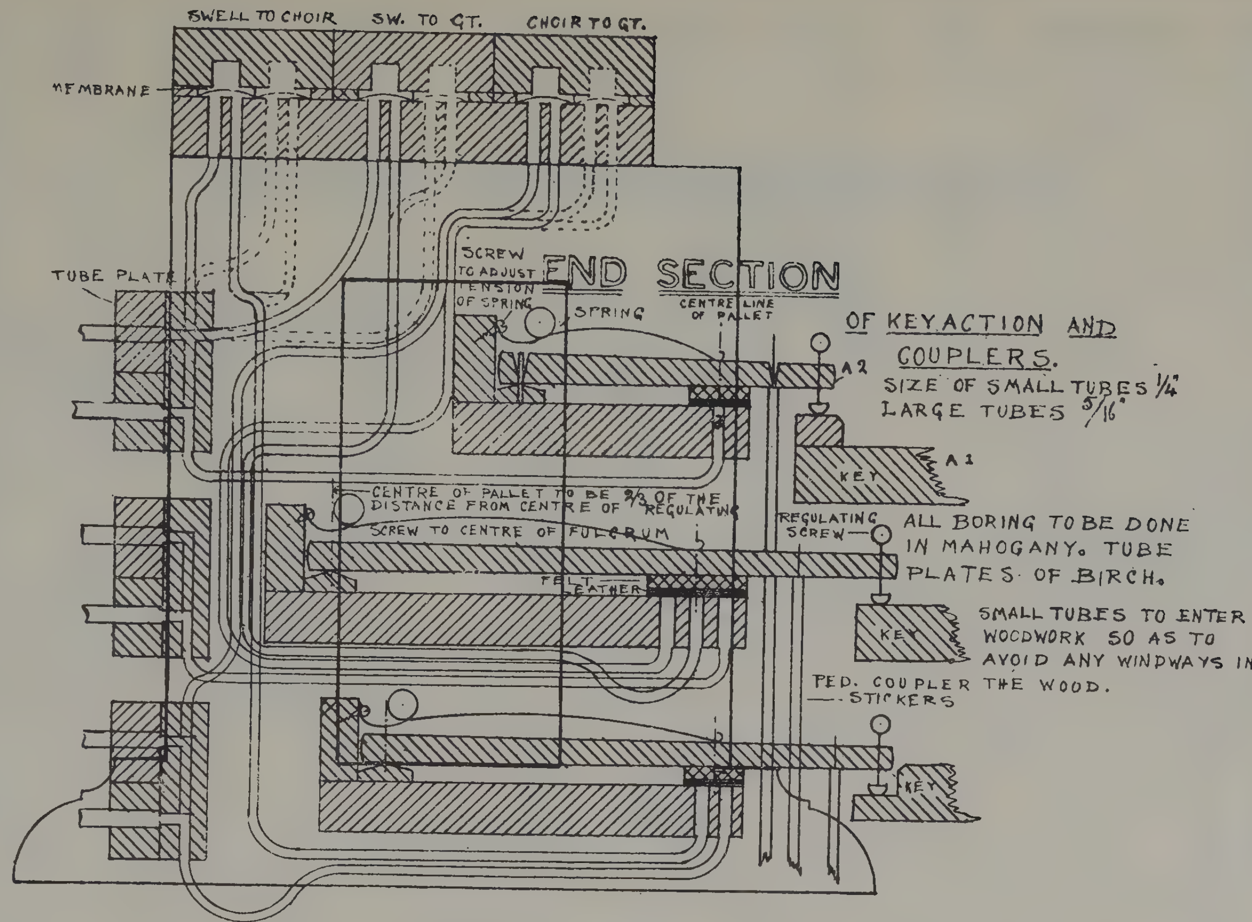


Plate 23

DETAIL OF KEY ACTION AND COUPLERS FOR A THREE MANUAL ORGAN [*Organ No. 2*] EXHAUST SYSTEM B[1]

is covered by the pallet of the bottom key C. On putting the coupler on, and depressing the bottom C on the Great manual, we shall get the bottom C on the Swell manual in addition.

If it were a Swell to Great Sub-Octave coupler, by depressing the Tenor C note on the Great manual, we should have, in addition, the bottom note C on the Swell, as the tube *CB* would, in this case, run to that note. Similarly, if it were a Super Octave to Great coupler, the tube *CB* would be taken into the octave above on the Swell, so that on the bottom note C of the Great being held, the note C, octave above, would sound on the Swell.

Plates 21 and 23 give sections of coupling actions in their entirety. Two notes are shown upon each coupler, one shown in dotted, and the other in continuous lines. They represent the positions of the C and C sharp notes respectively, as shown on the plan, Plate 22, Fig. 2.

On Plate 24 may be seen one style of key action on the supply system. The end of the key is attached to the wood lever or backfall, *A*. On depressing the key this lever is lifted up, so opening the pallet *B* and allowing the pallet *C* to close. The compressed air contained in the chamber *BC* now rushes into the groove *D*, or space between the bars, and so into the various tubes which lead into the auxiliary machine and several couplers.

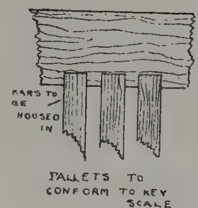
Upon releasing the key, the lever regains the position shown upon the drawing, the supply from the chamber *BC* is cut off by the pallet *B*, and the residuum of air left in the tubes and in the groove *D* is allowed to exhaust out at the small pallet *C*.

The section shown, as in the exhaust key action, gives the details of the action required for a single note. In an organ with a compass of fifty-eight notes, the part shown on Plate 21 would, of course, be multiplied fifty-eight times. In one of sixty notes, sixty times.

One method of effecting the coupling upon the supply system is shown upon Plate 25.

Upon depressing the key, the tube *A* which comes from the previously explained key action, is charged with air under pressure, so

Fig. 1



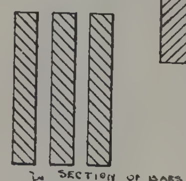


Fig. 2

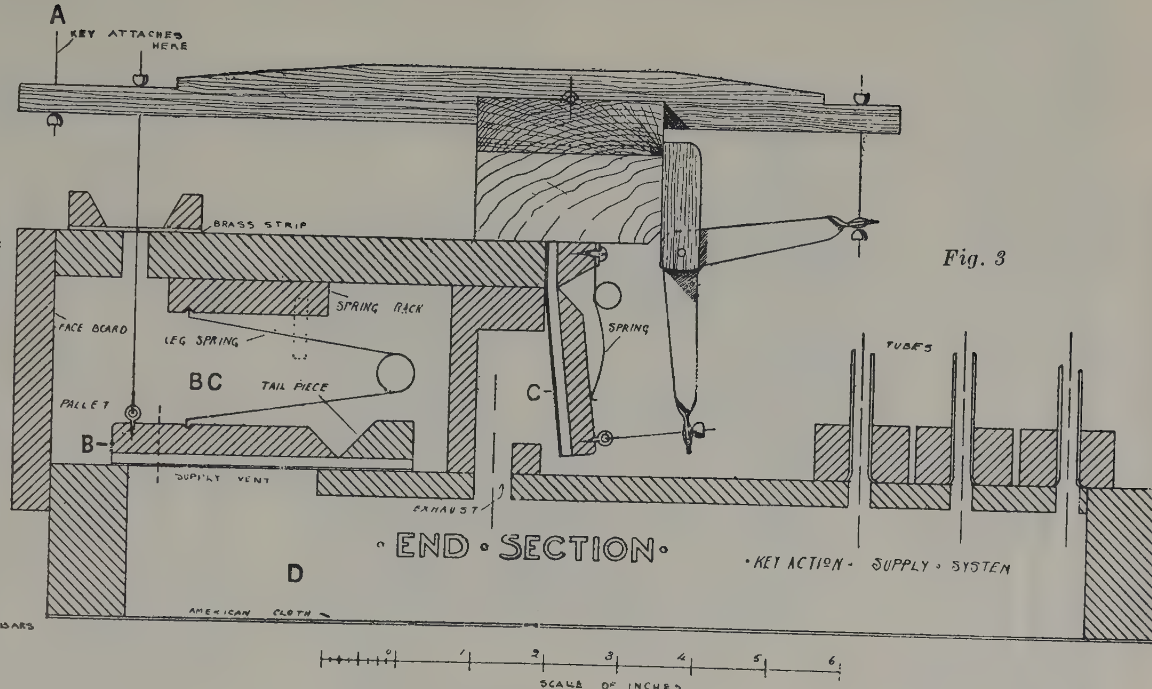


Fig. 3

Plate 24

DETAILS OF A KEY ACTION ON THE SUPPLY SYSTEM

Fig. 1. Detail of bars. Fig. 2. Section of three bars. Fig. 3. End section of key action

SUPPLY SYSTEM A

inflating the membrane B, which reverses the pallets 1 and 2. The groove C is now charged with air from the chamber AB, the valve D is forced over against the tube, and the air makes its escape via the tube E into the auxiliary machine. (See supply system auxiliary machines, page 62 and Plate 19.)

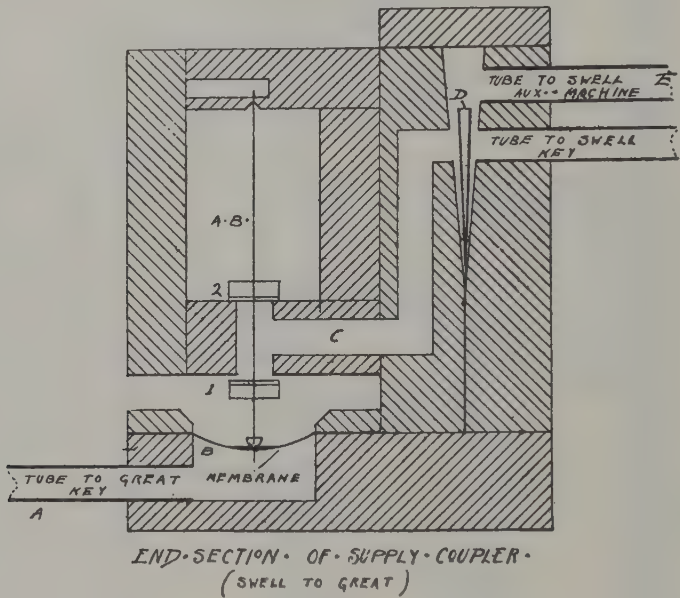


Plate 25

DETAIL OF A COUPLER ON THE SUPPLY SYSTEM A

The drawing given is intended for a Swell to Great, although there is no reason why it should not serve for any other coupler, as, for instance, an Octave or a Choir to Great.

The tube A goes to the key, and the tube E to the Swell auxiliary machine. Therefore, by depressing the key on the Great, the note into which the tube E is taken sounds in addition.

Valve D is known as a check valve. It might also be described, with some truth, as a gravity valve, as when blown to either side of the V-shaped compartment in which it is fixed, it there remains by reason of its weight. This kind of valve is necessary in the case of

a supply and exhaust in the key action, as shown on Plate 24. In the action shown on Plate 25, this valve prevents the supply via the double valve 1, 2, intended for the Swell main tube (which goes into the auxiliary machine) from being diverted back into the Swell key action; and again, were the valve absent, a supply introduced through the tube from the Swell key action would, in similar manner, become diverted and lost through the exhaust at pallet 1 in the coupler. This valve will accommodate a supply from either side, as it is free to move in either direction, and permits of an exhaust by reason of the fact that it remains passively where moved by the supply, the exhaust effecting no movement. Where two or more couplers are required, the main tubes, Swell and Great, pass through all the couplers belonging to them. This means with several couplers connected to the main tube, that several check valves have to be moved by the main supply before it can get through to the auxiliary action and so cause a note to sound; but owing to the ingenious construction of the valves mentioned, once they are moved they no longer hinder the supply until the couplers are used, when they again, to a slight degree, temporarily hinder the supply. Without becoming further involved in technicalities, it may be said that with the supply system, more couplers mean more check valves, and the main supply is retarded in proportion to the number of couplers placed on it. With the previously described system of exhaust it will be noticed main tubes are independent of couplers, and also check valves are not necessary, unless the "membrane" used to put coupling tubes out of action be so called.

This coupler (Plate 25) is brought on by admitting a supply to chamber *AB* and put off by exhausting it.

A variation on this form of coupler may sometimes be met with. It consists of the omission of the double pallet, membrane, and chamber *AB*, leaving but the "two way block" containing the check valve. In this case, the coupling tube enters groove *C*, and at its other extremity, at the key action (see Plate 24, Fig. 3) passes through a slide. This slide acts similarly to one on a slide sound-board. When the

coupler is off, the slide cuts off the supply, and when on, allows a free passage from the key action, groove *D*, into the tube.

The diagram represents a section of the coupling action necessary for one note, as is the case with most representations of end sections of action work, unless otherwise stated. The difference between unison, sub and octave couplers consistent with any tubular system, is not one of structure, but a matter of tubing merely. A complete coupling action is a sort of exchange where one tube is "switched" on to another automatically. With electric control the analogy becomes more literal.

Plate 25A shows a key action and coupling chest on a modified form of the supply system just explained.* In this case there is no exhaust to complicate matters.

Some general details of its construction are as follow:

The key action consists of a little "sound-board" with bars and pallets, made to the scale of the keys, but without slides. Swell and Great are identical. The coupling chest is similarly made with bars, like a sound-board, but to a larger scale than the key action. The actual scale of this part depends much upon tube diameters, but in any case it is advisedly made longer than the key action. As with the key action, the coupling chest is divided into compartments, one for each note on the manuals, with a further longitudinal division in the coupling chest, making two compartments, one for the Swell and one for the Great, for each note. Fig. 2 elucidates this construction.

The parts, key actions, Swell and Great and coupling chest, are shown more compact upon the diagram than is desirable in practice from the point of view of accessibility, this being notified by main tubes and the stickers to the keys being shown "broken."

The following describes what takes place when a key is depressed and all couplers are off:

The end of the Great key *d* lifts, opening pallet *e* in the key

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* This system has been referred to as supply system A^1.

action by means of the backfall and connection, thus supplying groove *g* with which the main Great tube communicates. This tube *h* is now supplied and after opening the "fly pallet" *i*, as shown on the diagram, the supply fills the Great compartment in the coupling chest

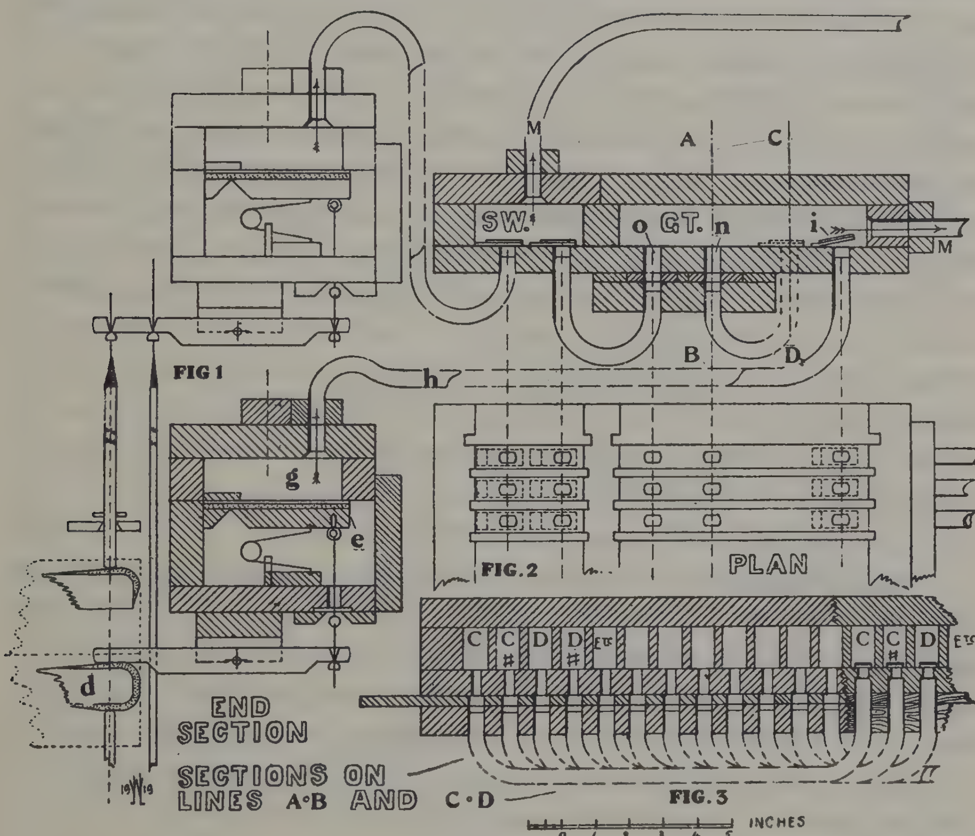

Plate 25A

DETAILS OF A KEY-ACTION. SUPPLY SYSTEM A[1]

Fig. 1. End section of key and coupling chest. Fig. 2. Plan of coupling chest Fig. 3. Sections on lines A-B *and* C-D

belonging to one note. All couplers being supposedly off, there is no egress for the supply but by way of the main tube *M*, which goes into an auxiliary action at the Great sound-board, so causing a note to sound.

When the key is released, the end of the key *d* falls to the position

shown on the drawing, pallet *e* closes as shown, and the supply is cut off. Immediately upon the cessation of a supply to any tube, pressure falls more or less rapidly to zero. This tendency is accelerated in this instance by the provision of a minute perforation in the auxiliary motor, which is always open. The static position of all the fly pallets, including *i* is a closed one. These pallets allow of the passage of air only in one direction, from the direction of the supply, and as the exhaust is at the other extremity of the tubes, no reversal of the air current takes place with the exhaust, unlike the state of affairs in the previously described key action and couplers illustrated on Plates 24 and 25. Also the main supply is independent of couplers, but the type of "check valve" is perhaps not such an accommodating one, and when couplers are on, the supply of the main tube is drawn upon to an increased extent. This description is equally applicable to the Swell key action, or to any further addition of manuals, which would merely necessitate a slightly different arrangement of the key action to permit communication with keys.

The coupling is effected in the following way:

Coupling tubes *o* and *n* pass through the bottom of the coupling chest, and through a slide and "upper" board, identical to the arrangement for controlling stops in a slide sound-board. Fig. 3 further illustrates this. Both couplers are shown on: when off, the slide interposes between the supply from the coupling groove and the tubes.

Tube *o* connects the Swell division of the chest to the Great division, so providing a Swell to Great coupler.

Tube *n* is taken from, say, the groove corresponding to lowest C on the keyboard to C octave above, so providing an Octave coupler on the Great. Fig. 3 illustrates this tubing. The two sections in this figure are on different planes, corresponding to lines *AB* and *CD* on the end section of the coupling chest, Fig. 1.

The valves are necessary to prevent coupling tubes acting in two ways. For instance, a supply intended for the Swell main tube *M*, introduced into the Swell portion of the coupling chest, would other-

wise become partly diverted into the Swell to Great coupling tube, *o*, and if the slide were on, would provide a Great to Swell coupler as well as a Swell to Great. Similarly with Octave couplers the omission of fly pallets would cause the duplication in every octave of any chord held on any portion of the keyboard.

This survey of the three styles of key action and coupling arrangements presents the essential differences between the exhaust system and the two supply systems already noticed as being generally used in modern organs. Any modifications there may be to the examples given concern details, and are not fundamental differences, and any system of tubular-pneumatics will be found to be related to one of these types. (See Appendix C)

MANUAL TO PEDAL COUPLERS (MECHANICAL) *

The mechanical manual to pedal couplers are on the same principle whether for exhaust or supply action, their office being to simply depress the keys on the manuals. It is possible to arrange a pneumatic form of manual to pedal coupler, but no advantage is gained by so doing.

The mechanical manual to pedal coupler action is the only part of the old tracker action organ that has successfully withstood the test of the " survival of the fittest." As the scale (distance from centre to centre) of the pedal board is much greater than that of the manuals, the coupling of the latter to the former has to be accomplished by means of a roller board. The roller, as everyone who has examined a tracker action knows, is a device for conveying motion laterally. The bottom note C on the pedal board does not come directly under the same note on the manuals; an iron roller, with an arm and connection to the bottom C on the pedal board, and the same to the bottom note C on the manuals, is therefore used. When the manual to pedal

* We have alluded to all organ actions other than those pneumatic or electro-pneumatic as being " mechanical."

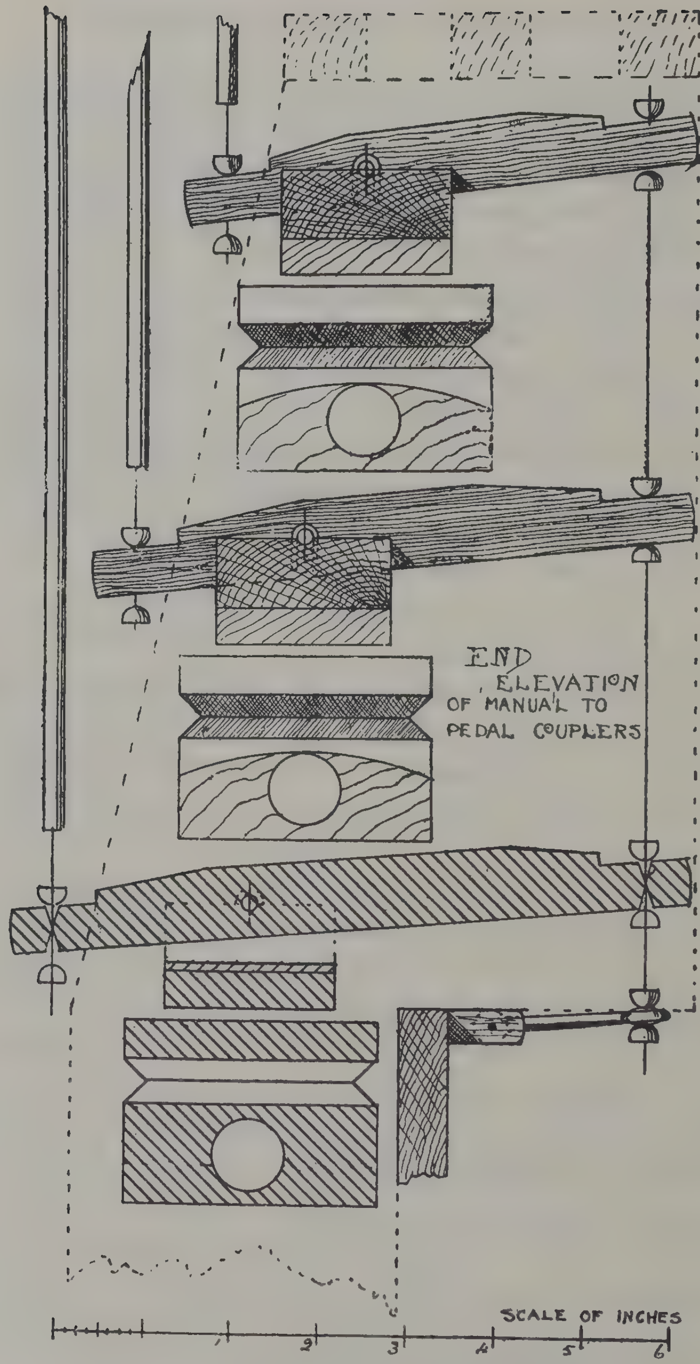

Plate 26

DETAILS OF MANUAL TO PEDAL COUPLERS. [*Organ No. 2*]

couplers are on, singly or collectively, depressing a pedal note will give a corresponding note on the manual or manuals, as the case may be.

The diagrams on Plates 21 and 26 give the device in detail. On Plate 27, Organ No. 2, the whole movement, as seen from the end, may be followed from the pedal to the key. When the backfall beams *M* (Plate 21), are in the position shown, the couplers are in action. On depressing a pedal, an arm, similar to the one shown at *P*, is pulled down. The two backfalls *MN* are pulled down at the front, and being centred on the beams *M*, the back part *N* is lifted up, communicating motion to the keys by means of the stickers *OP*. In the diagram the backfalls are held up in position by the motor *O*, which is inflated and exhausted of air as the coupler is put on or off, thus lifting the beam up and down. When down, the stickers *OP* are some distance from the keys, and move without affecting them when the pedal is depressed or released. Some builders retain a cam action of some description to effect this movement; in this case the action is purely and simply mechanical, no wind being used. Others, again, employ a motor of suitable capacity separate from the backfall beam, a lever movement effecting the rise and fall of the beam.

One beam, with its complement of thirty backfalls, constitutes a coupler. The leather buttons on the various wires and stickers form a means of regulating the different movements. The backfalls are set at an angle to move an equal distance above and below a level line taken from their centres.

DRAW-ROD AND STOP-KEY ACTIONS

The draw-rod action fulfills the same office for the draw-stop machine as the key action does for the auxiliary machine. It either exhausts and supplies, or supplies and exhausts, the tube into the auxiliary motor of the former.

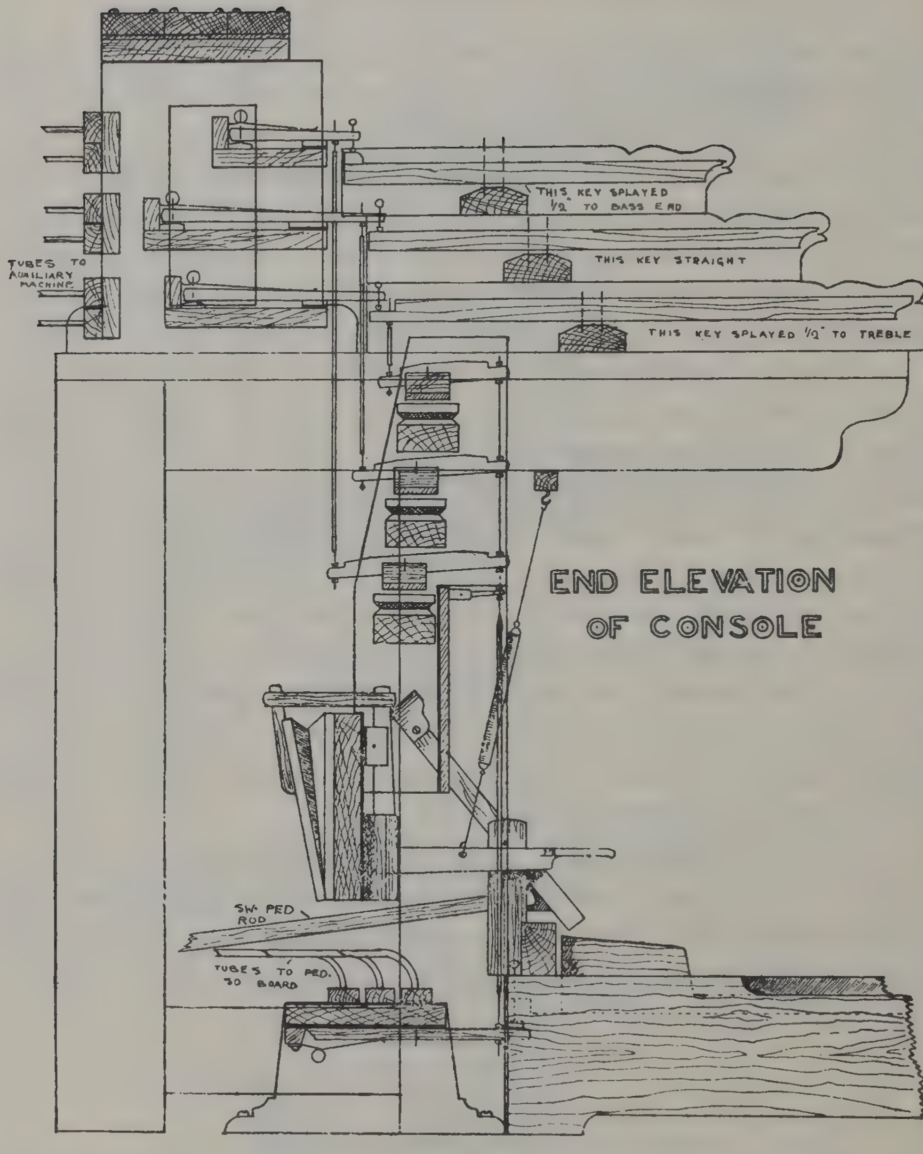

Plate 27

END ELEVATION SHOWING THE GENERAL ARRANGEMENT OF A THREE MANUAL ORGAN CONSOLE WITH DRAW RODS REMOVED. THE KEY ACTION AND COUPLERS OF THIS CONSOLE ARE SHOWN IN DETAIL UPON PLATES 23 AND 27, THE COMPOSITION PEDAL (FAN NOT SHOWN) UPON PLATE 32 AND THE PEDAL MACHINE ON PLATE 20.

[*Organ No. 2*]

The time-honoured form of draw-knob is still in general use to-day. It is a survival from the old tracker action instrument. The knobs are arranged in their various groups upon each side of the key-board, at an angle of forty-five degrees.

The stop-key action is, comparatively speaking, a new departure from the draw-knob action. Considered without prejudice, it is an

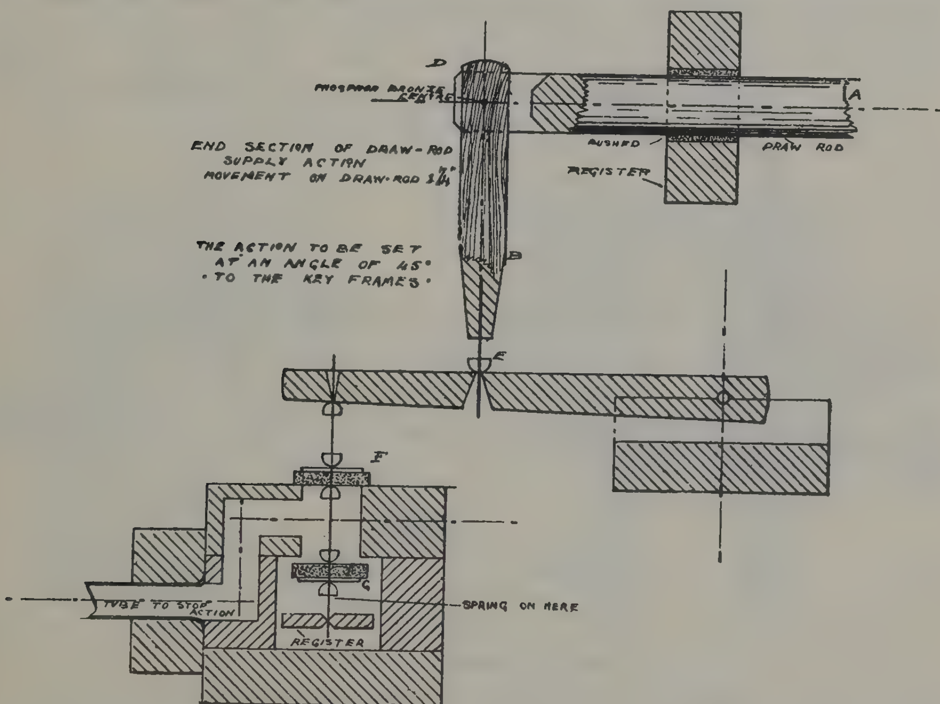

Plate 28

DETAILS OF A DRAW-ROD ACTION, EXHAUST SYSTEM B

eminently superior method of controlling the stops. The stop-keys, as the name implies, are after the style of the key-touches. They are arranged over the keyboards, and directly in front of the organist. In this position they are under easy control of either hand, and are always in sight. In addition, to an expert player, their ease of manipulation almost renders the application of composition movements unnecessary.

Plate 28 gives an example of one style of draw-rod action. The round rod *A* is continued outside the "jamb," and the ivory draw-knob is inserted into it. On pulling this out, the cam *B* is taken with it at *D*, the other end *E* throwing slightly upwards, so releasing the double-acting pallet *FG*, which is moved to an opposite position to that shown, by means of a wire spring. The air in chamber *G* now being cut off from the tube, the latter exhausts through the now uncovered hole at

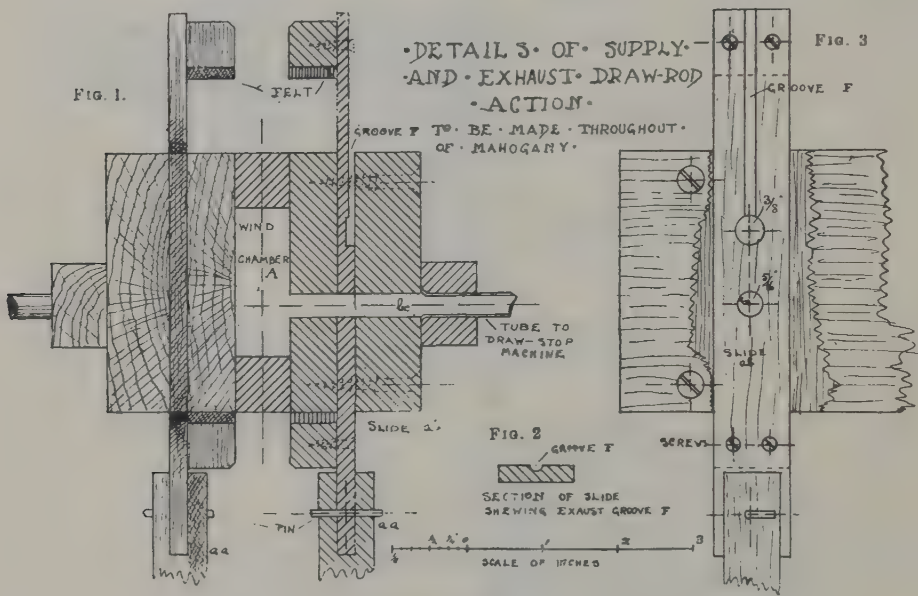

Plate 29

DETAILS OF A DRAW-ROD ACTION, EXHAUST SYSTEM B
Fig. 1. Section. Fig. 2. Detail of slide ab. Fig. 3. View showing method of boring

F, so putting the stop action on. Reversing the rod by pushing in the stop-knob, brings the action to the position shown, supplying the tube with air, and so putting the stop action off. This is the exhaust action. By a slight modification, this style of movement may be altered to the supply system.

On Plate 29 will be seen another style of draw-rod action. It is after the manner of the slide valve in an engine. The draw-knob is on the end of the rod *aa*. In the position shown, the air from chamber

A (section) is allowed to pass through the hole in the slide, and so supply the tube. On pulling the knob out, the slide *ab* is drawn forward until the exhaust groove *F* corresponds to the tube hole *bc*, so allowing the air from the tube to exhaust out through the groove *F*. By reversing the position of the exhaust and supply holes, the action may be made "supply." There are numerous other types of draw-rod actions. but if the reader thoroughly understands the working of the ones shown, a little patience will enable him to grasp the principle of any form of action it may be his fortune to encounter.

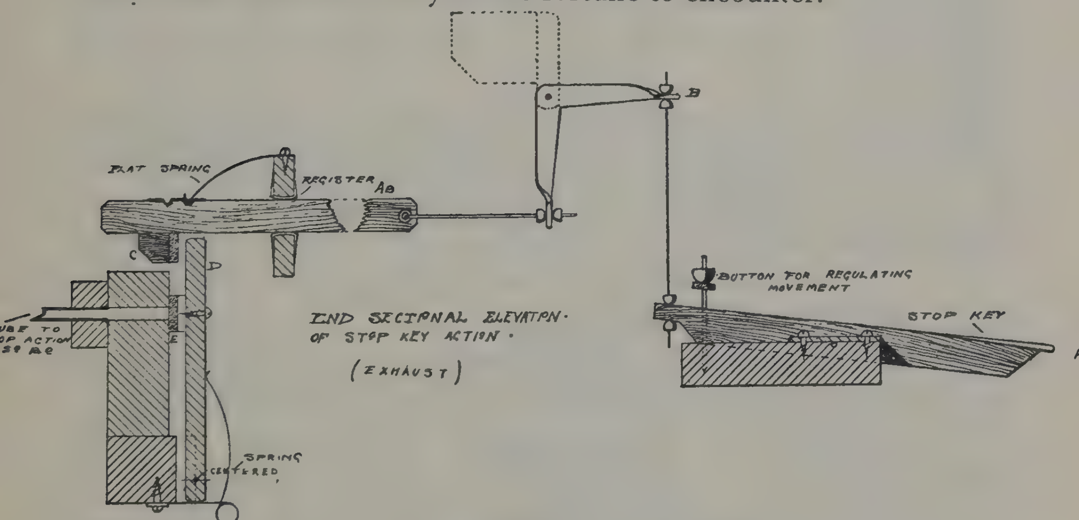

Plate 30
SECTION OF A STOP-KEY ACTION, EXHAUST SYSTEM B[1]

Plate 30 shows one style of the stop-key action. On pressing down the stop-key *A*, the arm of the aluminium square at *B* is pushed up, so drawing forward the flat rod *Ab*. The little block *C* on this rod engages the jack *D*, to which is attached the pallet *E*. The end of the tube *de* is now uncovered, and the air promptly exhausts from it. The rod *Ab*, it will be noticed, is shown considerably foreshortened. The length of this rod, in practice, is determined by the style of composition action adopted, as the fans engage on pins or blocks on these rods.

COMPOSITION ACTIONS

As every organist knows, composition pedals are devices for throwing on or off certain pre-arranged combinations of stops at the will of the player.

The number of these movements is determined by the size of the instrument, i.e., the number of stops it contains. They may vary from two to four pedals or pistons for each manual. On very large organs, with four or five manuals, pistons would be used, as the use of pedals would be a needless expense, even if they could be crammed into the limited space.*

Where the old mechanical form of draw-rod action is used, the composition action is of necessity somewhat cumbrous and clumsy. After a few years have elapsed, this style of action usually becomes fearfully stiff, taxing the strength of the organist in no small degree. In this case, the fans are large pieces of hardwood, which engage upon blocks screwed and glued to the trace rods. This antique form of composition action may be seen on organs built about twenty years ago, although it has not survived amongst the present-day builders.

Where pneumatic draw-rod actions are used, the composition action is incomparably neater, quieter, easier and more effective. It exists in several forms, which may be divided into two classes, mechanical and pneumatic. The mechanical action is usually some form of light steel or iron frame, termed a fan, suitably bushed and centred to engage upon blocks fixed to the draw-rods.† They are arranged in pairs, each acting in an opposite direction. An ordinary book furnishes an excellent example of a composition fan. If we stand it upon end, with the covers closed, we have the fan at rest. Opening both of the covers simultaneously to about an angle of thirty

* For a large organ composition pedals may be reserved for acting upon the pedal organ only, and pistons used for manual combinations only. A further complication of the idea is the use of a coupler to connect the two when desired.

† Refer to Plate 31A for a mechanical composition action.

degrees, we have the position of the fan when the composition pedal is depressed. The draw-rods are arranged one above the other, usually in a double line, as a glance at an organ console will show. We will suppose we are dealing with a double-acting fan, as described, intended to throw out those stops on the Great organ giving a *pianissimo* effect.

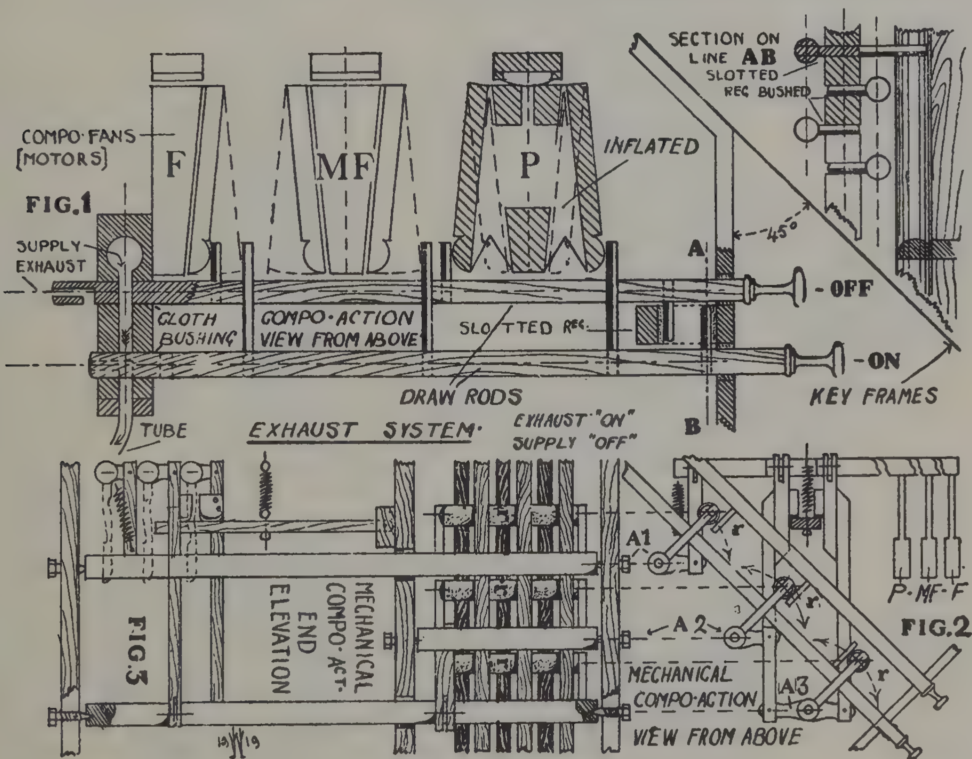

Plate 31A.

COMPOSITION ACTIONS.

Fig. 1. Plan of pneumatic composition action, with draw-rods, further details on Plate 31. Fig. 2. Plan of mechanical composition action. The fans are centred at A1, A2. A3, and move at r *in the directions indicated by the arrows, according to which pedal is depressed. Fig. 3. End elevation of the same mechanical composition action.*

If we imagine ten stops to be on this manual, three of them would probably give the effect required. In each of these three draw-rods would be fixed a dowel or peg of wood, in such a position that as the fan was opened, it would engage upon these pegs and so throw the

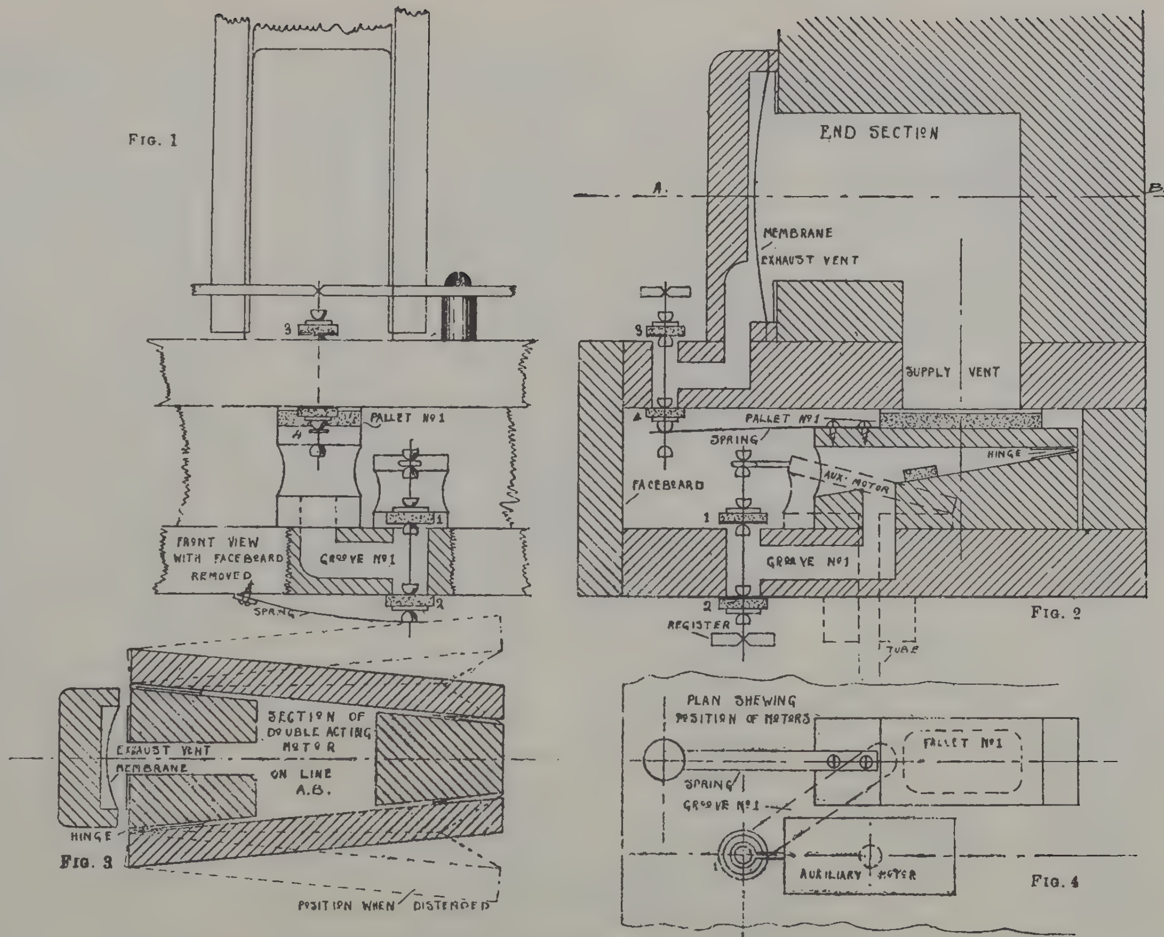

Plate 31

DETAILS OF A PNEUMATIC COMPOSITION ACTION OR FAN, EXHAUST SYSTEM B[1]

Fig. 1. View from the front with the faceboard removed. Fig. 2. End section. Fig. 3. Section of the motor. Fig. 4. Plan showing position of small motors and the groove (No. 1)

stops out. On the seven remaining draw-rods, pegs would be fixed engaging on the fan working the opposite way, enabling this fan to throw all or any of the seven draw-rods in, if they should, at the time of depressing the pedal, be out. Thus, no matter what stops were out, depressing this pedal would always bring on the three pre-arranged

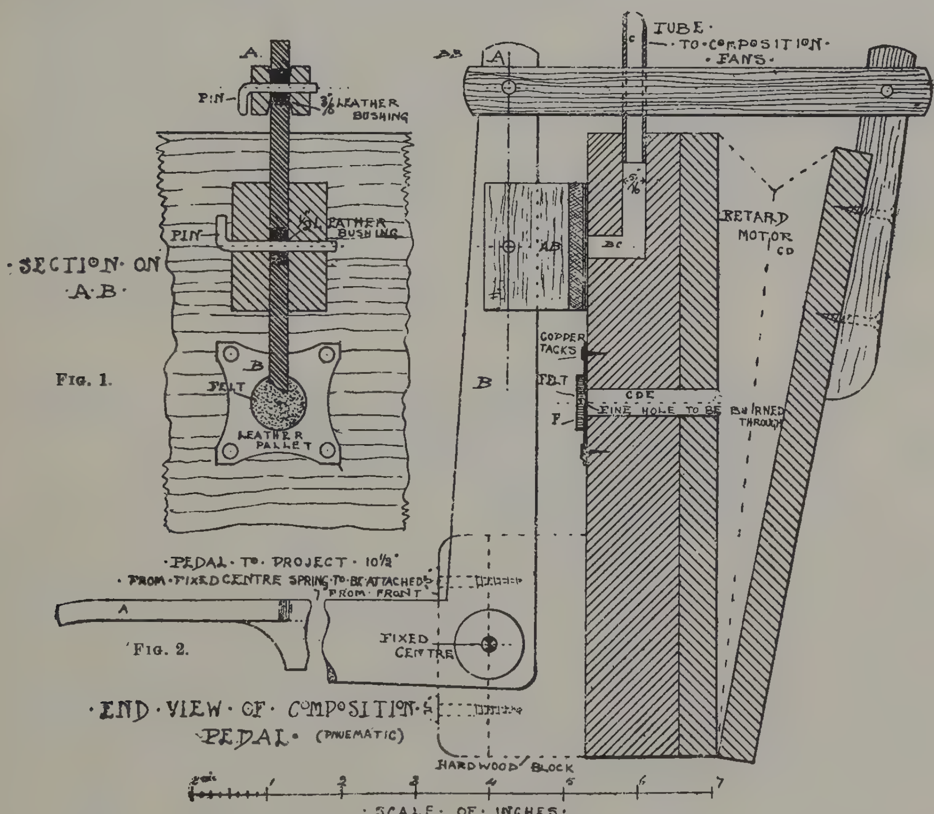

Plate 32

DETAILS OF COMPOSITION PEDAL FOR ACTUATING THE FAN SHOWN ON PLATE 31

Fig. 1. Section of the pedal on line AB. Fig. 2. End sectional view

stops giving the *pianissimo* effect. If, on the same manual, all the stops were required for the *fortissimo* pedal, this fan would be single acting, as it would not be necessary for any of the stops to be thrust in.

On pneumatic composition actions, the metal or wooden fan is replaced by a large motor. If we further pursue the simile of the

book, the two covers will represent the moving top of the double motor. (See Fig. 3, Plate 31). When supplied with air, the motor flies open. When the air is allowed to exhaust, a spring returns the motor to its closed position

Plate 31 gives the details of the action supplying and exhausting a pneumatic composition fan. The auxiliary motor (in the drawing, Fig. 2, shown dotted and marked) is exhausted and collapsed through the tube, on the pedal or piston being depressed. The double pallet 1 and 2 is now reversed, and exhausts the large pallet motor 1. As this motor descends, it reverses the double pallet 3 and 4, to which it is attached by a flexible steel spring, so closing the exhaust vent by forcing over the membrane, and allowing the air rushing through the supply vent from the wind chamber to throw open the double acting motor (section on *AB*).

With the release of the composition pedal or piston, the action regains the position shown on the diagram, the air from the double motor exhausting through the exhaust vent at the membrane.

The pedal for use in conjunction with the above pneumatic fan is shown on Plate 32. On pressing down the pedal at *A*, the part at *BB* describes an arc from the fixed centre. The pallet *AB* is lifted clear of the tube hole *BC*, allowing it to exhaust the auxiliary motor in the fan action via the lead tube. As the pedal at *BB* goes forward, it closes the retard motor *CD*, the air escaping through the groove *CDE*, and so out at the sides of the leather pallet *F*.

Releasing the pedal, a spiral spring exerts an upward pull on the pedal at *A*, reducing the air in the motor *CD*, which gradually returns through the small hole in the now closed pallet *F*. The tube hole *BC* is now closed by the pallet *AB*, allowing the auxiliary motor to fill up. The speed at which the pedal is allowed to return can be increased by enlarging the hole in the pallet *F*, or the contraries. The section *AB* is as seen from the front, taking the section on the line *AB*.

PISTONS

Pistons are devices for controlling the composition fans from the keyboard. They are little buttons of metal or ivory, placed either as shown on Plate 33 or on the key slip, i.e., the thin piece of wood directly underneath the front of the keys.

As will be seen from a glance at the drawing, they consist of a pallet, covering the end of the tube taken into the auxiliary motor in the composition action. When depressed, the pallet uncovers the end of the tube, allowing the auxiliary motor to exhaust at the pallet hole. When released, they render the tube air-tight, allowing the auxiliary motor to recover.

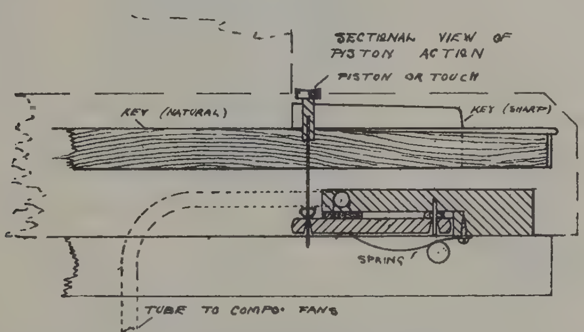

Plate 33

PISTON MOVEMENT. EXHAUST SYSTEM B[1]

Pistons may be installed in conjunction with composition pedals, if desired; or either movement may be installed singly.

Where a detached console is used, and it is found difficult to use pneumatic composition actions after the method shown above, a much simpler form of pneumatic fan may be resorted to. This consists of two motors, one situated at the pedal, and one, as previously described, single- or double-acting, at the draw-rods. A tube of large bore connects the two. On depressing the pedal, the air is compressed in the one motor, and traversing the tube, it throws open the fan at the draw-rods. By reversing the motors, and suitably arranging the valves, the

fan may be moved by suction, the lower motor drawing the air from the one above.* This system is similar to the pneumatic poppet pedal shown on Plate 35.

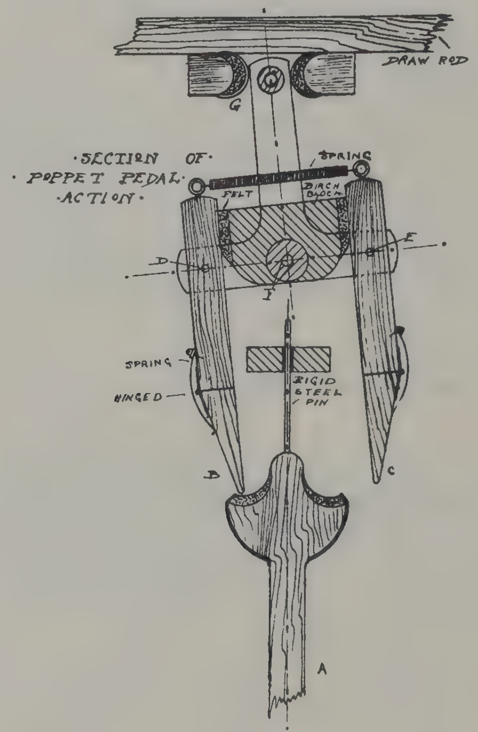

Plate 34
A MECHANICAL POPPET PEDAL ACTION

INTERCHANGEABLE COMBINATION ACTIONS

There are several forms of the interchangeable action. The combinations on the various pedals or pistons are not permanently fixed, but may be changed by the organist to suit his individual taste or requirements of the moment. This idea, of course, involves further elaboration of mechanism.

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* A method sometimes used by Hope-Jones. It is not safe practice to use pneumatic actions of this kind, for they are not, as a rule, durable.

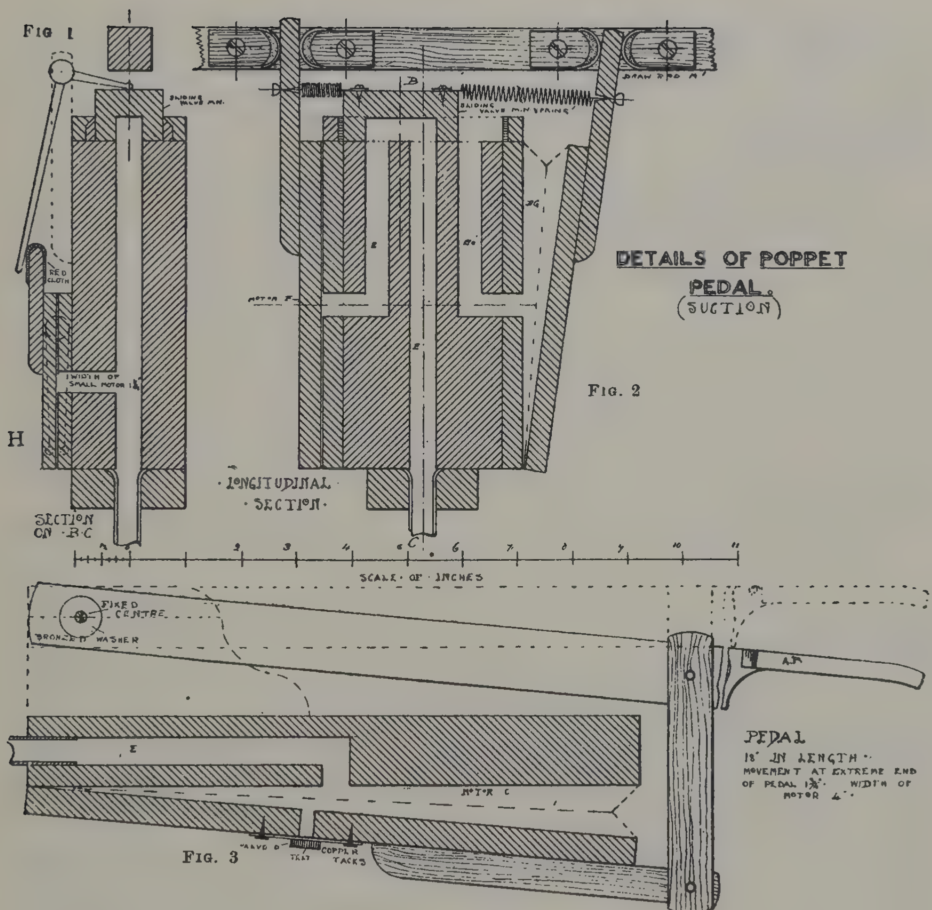

Plate 35

DETAILS OF A PNEUMATIC POPPET PEDAL, SUCTION ACTION

Fig. 1. End section. Fig. 2. Section showing grooving. Fig. 3. Section of the pedal

POPPET PEDALS

These pedals come under the same category as the composition pedals. They are actions acting solely upon one stop, putting it out and in with a single pedal. Usually the Great to Pedal coupler is the stop acted upon.

A variety of ingenious mechanical movements have from time to time been perfected for this purpose. One of them may be seen on Plate 34. The rod *A* is pushed upwards as the pedal is depressed. The part *G* describes an arc from the centre *F*, pushing the draw-rod to the right, and at the same time the rod *C* gains a position similar to that held by the rod *B* previously. On the pedal being released, the rod *A* returns to the position shown, the rod *C* engaging for the return movement. On depressing the pedal now, the stop is pushed in. The little rods *B* and *C*, it will be noticed are hinged.

Plate 35 gives the details of a suction-action* pneumatic poppet pedal. The pedal *AB*, Fig. 3, on being pushed down to the position shown, draws the air from the motor *FG*, Fig. 2, via the grooves *EE*, with the result that the rod *M* is moved to the right. Simultaneously, the air is drawn out of the small motor *H* (section on *BC*, Fig. 1), which holds down in position the sliding valve *MN* by means of the device shown. Directly on the release of the pedal *AB*, Fig. 3, the motor *H*, Fig. 1, is opened by the springs on each of its sides, so relieving the pressure from the sliding valve *MN*, which is pulled to the opposite side by the spiral spring, so preparing for the return movement.

There are also pneumatic poppet pedals worked on somewhat similar lines to the composition action shown on Plate 31, but the two movements, out and in, being on the same pedal, make this style of action complicated.

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* This is illustrated by way of completeness, but actions not working on the compressed air from the organ bellows are used only under circumstances mentioned in the Introduction to this volume.

ELECTRO-PNEUMATIC ACTIONS

Plate 36 shows the Hope-Jones form of electro-pneumatic action. As will be seen from the diagram, it consists of an electro-magnet, disc armature and armature or valve seat. On the end section of the action these various parts may be seen in position. The action as shown is at rest, the disc armature being kept up against the valve seat, allowing the air from the action box to pass through the interstice between the two arms of the magnet, and so supply the secondary motor. On completing the electric circuit by depressing the key, the iron core of the magnet is temporarily magnetised, attracting the disc armature against the pressure of air in the action box, uncovering the hole in the valve seat, and closing the interstice in the magnet top, thereby allowing the secondary motor to collapse. The secondary and primary motors are now reversed and the action is on. On releasing the key, the flow of current round the magnet windings is stopped, the pressure inside the action box blows up the disc, and the secondary motor is supplied, so putting the action off. The armature valve seat is made of brass, being screwed into the wooden portion underneath, so forming a means of regulating the movement of the disc. There is always a slight amount of residual magnetism in these magnets; to overcome this, the side of the iron disc towards the magnet is covered with paper, the thickness varying according to the power of the current and pressure of wind. The movement of the armature disc varies from one hundredth of an inch, never moving less than this, but frequently more.

The current is usually supplied from a battery of wet or dry cells, or from accumulators, as the current is required at a very low voltage, seldom exceeding eight volts. On account of the low pressure current, the sparking at the numerous contracts is negligible, being only just perceptible, in complete darkness. There is no limit, theoretically

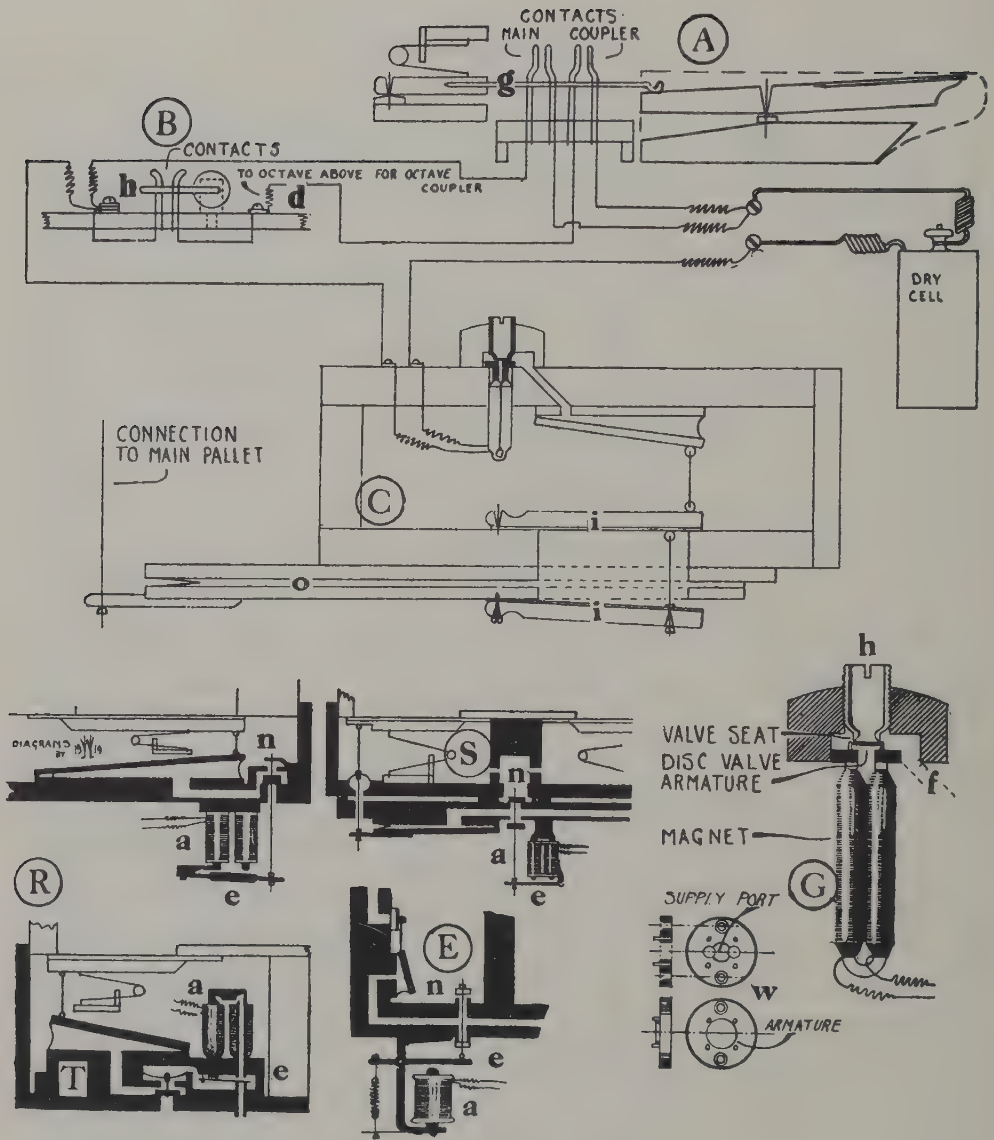

Plate 36

ELECTRO-PNEUMATIC ACTIONS

A, B, C.—Semi-diagrammatic representation of the Hope-Jones electro-pneumatic system.

A.—The key-action. The contact bar at g *rises when the key is depressed.*

B.—Method of coupling by means of switch h, *which is controlled from the console: this switch is shown "on," connecting the two contacts: the wire* d *comes from the coupling contact.*

C.—Auxiliary machine: main motor o, *controlled by double pallet* ii, *which is moved by the small motor: this small motor (secondary) is under control of the magnetically moved disc valve.*

G.—Details of the electric portion of the auxiliary machine: at h *is the brass valve seat against which is lifted by air pressure the armature (or disc valve). The magnet is of the horse-shoe type, the top being circular, as shown in detail,* w, *with and without the armature.*

R. S. T. E.—Four other systems of electro-pneumatics.

R.—Dr. Péschard's patent (1864) in which the magnet a *attractcs the armature* e, *which moves the (secondary) valve* n, *so controlling the admission of air to the speaking pipes when the main motor is exhausted.*

S.—Barker's patent (1868) similar to the above, except that it is "supply," and the sound-board as shown has two main pallets for each groove. This, and the foregoing system, are obsolete.

T.—Schmoele and Mols patent (Antwerp, 1881). In this action the magnet a, *by attracting and releasing armature* e, *controls the secondary "puff," and thus the valve inlet and outlet of the main pallet motor. A supply comes through one arm of the magnet, which the armature cuts off when attracted upwards. The units in this action are not readily accessible.*

E.—Roosevelt's method of electric control. This is the only system, to our knowledge, which approaches the simplicity of the Hope-Jones action. The magnet a, *by attracting and releasing the armature* e, *upon which rests the valve* n, *controls the inlet and outlet of air to the Roosevelt motor, which supplies a speaking pipe. The illustration,* E, *is not correct as a "working" drawing.*

speaking, to the length of cable between the console and the action boxes. In other words, the console may be detached to any distance without affecting in the least the promptness of repetition of the action.

The weak point of the electro-pneumatic action lies in the present form of make and break contact. Each additional coupler means an increase in the number of contacts, with a consequent increase in the potentiality for failure. These contacts are, of necessity, fragile and of fine adjustment. In busy manufacturing centres, the fumes and gases suspended in the atmosphere exert a chemical action upon the contacts and cables, corroding and often eating them completely away at exposed places. The contacts and contact pins at the key touches are rendered more reliable and free from corrosion if made of platinum and gold respectively, but the costliness of these metals forbids their use throughout the instrument.

Bearing these facts in mind, it cannot be conscientiously claimed for the present-day electric action that it is as reliable and as lasting as the pneumatic action. It is not recommended, therefore, in positions where it is possible to use pneumatic action alone. (See succeeding note on tubular and electric action combined.)

In buildings where it is necessary that the console be removed more than about sixty feet from the organ, the certainty of an instantaneous response to the key touch more than counterbalances the risk of an occasional "bad contact"; for, when first-class materials and workmanship are put into an electric organ, a bad contact should be the exception rather than the rule.

Undoubtedly, as the years roll on, improvement upon improvement will revolutionise the electro-pneumatic action, until it will at last attain recognition as the perfect means of communication between player and organ pipes. At the time of writing, however, very little advance seems to have been made upon the conceptions of Hope-Jones, but we will charitably suppose this to be the calm preceding the storm of ideas gathering in the future.

TUBULAR AND ELECTRIC ACTION COMBINED

There has been used, with considerable success, a combination of electric and tubular pneumatic action. The electric portion ends before it reaches the auxiliary action boxes, doing away with the necessity for using magnets in these boxes, all coupling being done pneumatically.

This system is only used where a detached console is necessary.

The pneumatic coupling chest, upon any of the previously explained systems, is situated with the main portion of the organ. Instead of carrying the tubes from the couplers into the key-action, as in the orthodox way, they are taken into a small action box. This action box is worked electrically, by means of magnets, a cable connecting it to the key touches at the console.

Upon depressing a key, a magnet is put in circuit, so operating a small motor controlling a valve.

This valve, if the action is upon the exhaust system, permits the egress of the air from the tube going into the auxiliary machine; if upon the supply system, it is so arranged to supply the tube with compressed air. After this, in either case, the action is the same as an ordinary tubular system.

The advantages of this are: absence of all electric couplers, number of contacts necessary reduced to one for each key, and further, as with the ordinary electric action, the console may be removed to any position regardless of distance.

This form of electric action is, without the slightest doubt, preferable to the older system, and may be employed with confidence.

CRESCENDO BOXES

Crescendo boxes, or as they are commonly called, swell boxes, are huge boxes built around sound-boards and pipes in order to obtain *espressivo* effects. This is the only method, or at least, the only practical method possible, to obtain these effects in organs.

At one time a great many builders constructed swell boxes of brown paper stretched upon light wood frames. As many as four separate frames of this material, with an air space between, being employed. Various other materials have been employed; amongst them may be mentioned ordinary building bricks.

At the present time wood is the material that has found universal approval; the top, sides and back of the boxes being constructed of match-boarding nailed upon a frame with a space between of about two inches.* This space is filled up with tightly packed sawdust. Most swell boxes are brown papered upon the inside.

Even when opened to their fullest, all swell boxes muffle the tone of the pipes enclosed. A great deal of sound is dissipated by repeated reflection from the top and sides. Much of this may be obviated by having the top of the swell box concave or at an angle, and it is an advantage, where expense can be made subservient to effect, to have the back corners of the box also concave.

It was formerly the practice, when swell boxes were generally of smaller dimensions than they are at the present day, to have an aperture in the back of the box. When the shutters were open, a large pallet covered this aperture. Upon closing the shutters, the pallet uncovered it, so permitting the free escape of the air which came through the pipes. A trunk usually conveyed this air to a distant part of the building in order that the effect of the box might be improved.

As present-day boxes are constructed altogether upon much more massive lines than was formerly the case, and as there are of necessity many small outlets consequent upon their huge size, the above-mentioned device is dispensed with.

Some form of tuning flap is provided upon swell boxes in order that the reeds may be easily reached. Some are also provided with one or more doors in order to effect an entrance into the interior; but usually, doors are reserved for large boxes.

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* Or as much more as may be desired.

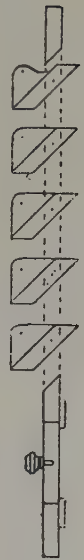
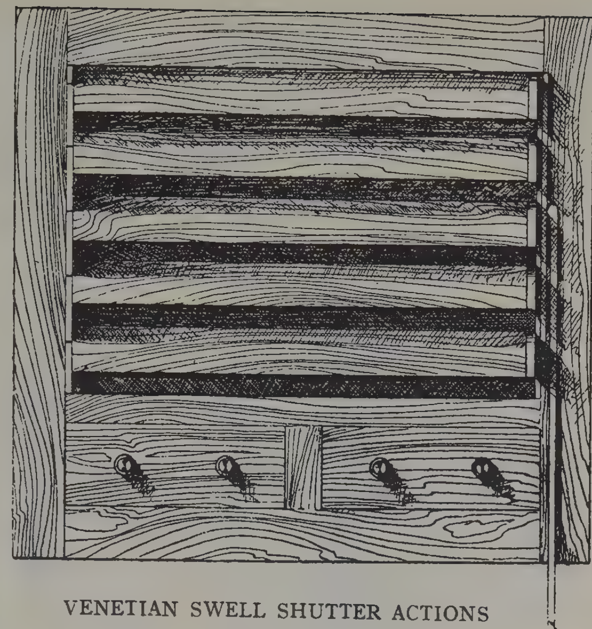


Fig. 1



VENETIAN SWELL SHUTTER ACTIONS
HORIZONTAL AND VERTICAL

Fig. 2

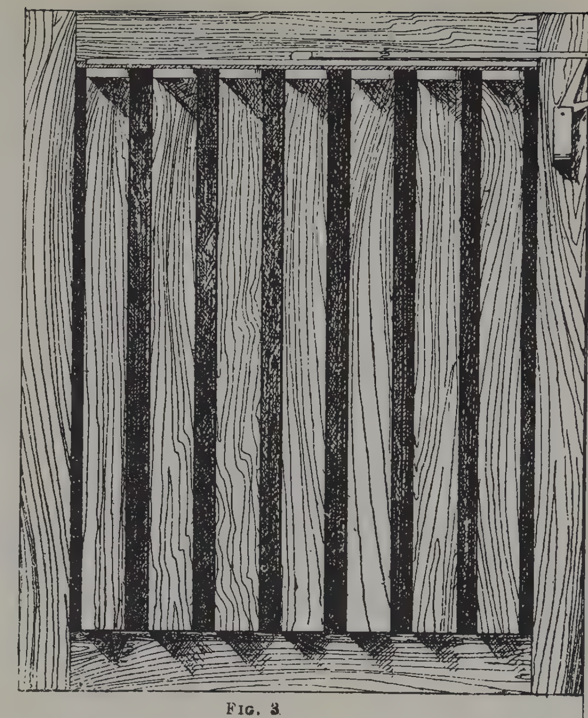


Fig. 3

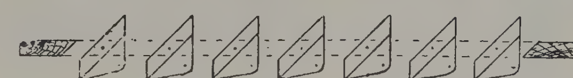


Fig. 4

Plate 37

VENETIAN SWELL SHUTTER ACTIONS

Fig. 1. Section showing position of shutters when open. Fig. 2. Front elevation, horizontal design. Fig. 3. Front elevation, vertical design. Fig 4. Section showing position of shutters when open.

Venetian shutters form the most effective means of opening and closing the box. The two ways of arranging the shutters are shown upon Plate 37. The vertical method is usually employed in conjunc-

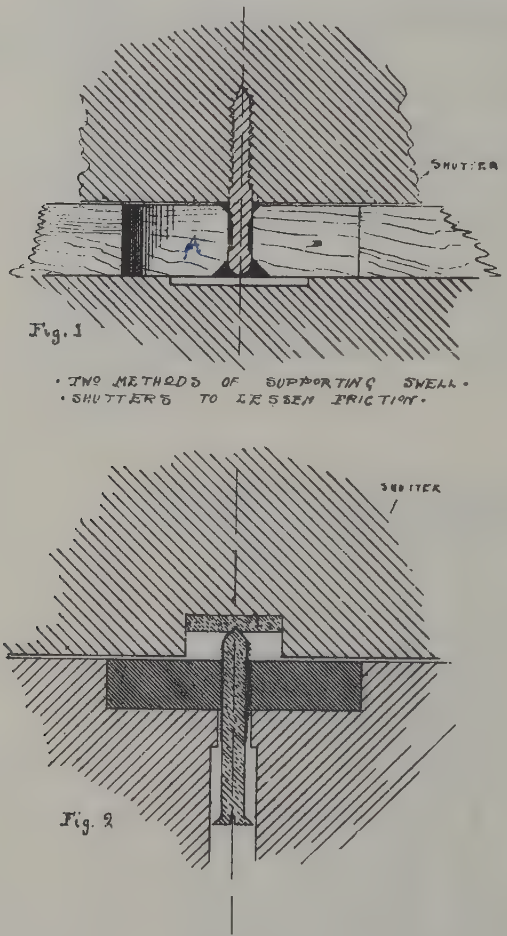


Plate 38

TWO METHODS OF SUPPORTING SWELL SHUTTERS IN ORDER TO ELIMINATE AS MUCH FRICTION AS POSSIBLE

tion with a balanced pedal, although it is possible to employ the horizontal shutters with either description, balanced or otherwise.

It is usual, when horizontal shutters are used, to have them open as shown upon the diagram, but very expressive effects have been

obtained from swell boxes with the shutters opening upwards, oppositely to the way shown in Fig. 2.

Where the reeds and flue-pipes can be tuned from the inside, the effectiveness of the box may be considerably enhanced by taking the shutters the entire height of the front, as shown upon the diagram, Fig. 4.

Two methods of supporting vertical shutters are shown, Plate 38.

In Fig. 1, the weight of the shutter rests on the pin with the rounded end, which in turn revolves upon the little iron plate underneath. A piece of wood, cut to the shape of the hollow *AB*, prevents the shutter slipping out by holding the pin in position on the plate.

In Fig. 2 the pin is screwed through from the bottom, the little iron plate being in the shutter. The small plate has a tiny hole punched in its surface into which the point of the pin fits, thus retaining the shutter in position.

SWELL PEDALS

There are three methods for working the shutters in swell boxes, representing the three styles of organ actions in common use—mechanical, pneumatic and electro-pneumatic. Of the three, the mechanical method, by means of direct communication with the shutters, is the most frequently resorted to.

The two boxes shown on Plate 37, are opened and closed mechanically. A series of rods and levers connect the rod at the side of the box with the *crescendo* or swell pedal. On depressing this, the shutters are opened in a corresponding degree. If the pedal is of the balanced description, it is usually placed approximately in the centre of the console. In this case it is a flat piece of wood, similar to a blowing pedal on a harmonium, and may be left open or closed, or in any intermediate position, when the foot is taken off.

The unbalanced pedal is placed on the treble side of the console, under the control of the right foot. It is retained fully opened by some form of catch, usually a notched stick. On the catch being released, the shutters close by their own weight, or are assisted by a spring, no intermediate position being possible unless held so by the foot or by an additional notch in the catch.

With either pneumatic or electro-pneumatic action, each shutter is under the control of a large motor. These motors are generally arranged on a level with the top of the box, but slightly in advance of the

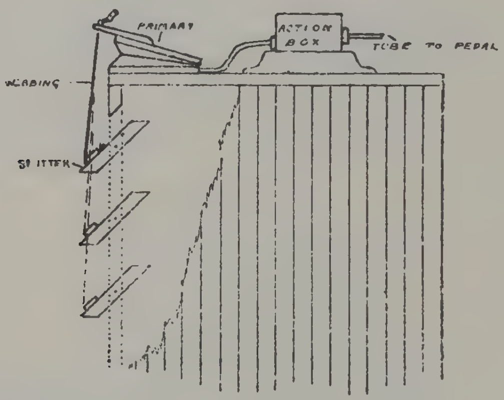


Plate 39

PNEUMATIC SHUTTER ACTION

same. A suitable connection from the motor to the shutter is made, sometimes a piece of stout webbing. On the pedal being depressed, these motors are inflated one by one, so pulling open the shutters to which they are attached, and obtaining a *crescendo* effect. There is one primary motor for each shutter, the secondary and auxiliary motors being arranged in an action box. (See diagram, Plate 39.)

In the case of electro-pneumatic shutter actions, the connection to the pedal is by electric cable, but if entirely pneumatic, by small compo. tubes, i.e., composition tube, made of an alloy of tin and lead, coated with tin.

TREMULANTS

The first form of tremulant or tremolo was rather crude in its application. It consisted of a large motor, to the top of which was attached a long flat springy piece of steel. Upon the spring was a small weight, capable of being fixed at any desired position. The air inlet to the motor was controlled by one pallet. Another pallet was pulled open by a tracker action when the tremulant was required, with the result that the motor was suddenly inflated, setting the weight upon the spring into violent oscillation. It continued thus vibrating for as long as the pallet was left open, the motor communicating its motion to the air inside the wind trunk. By this means an undulating effect is produced from the pipes. This form of tremulant is rather erratic in its behaviour, and has been superseded by the improved form shown in section upon Plate 40.

A tube goes into the auxiliary motor *A*, and is continued into a suitable draw-rod action.

Upon exhausting this tube, the motor *A* is deflated, reversing the double pallet 1 and 2. The motor *B* now exhausts via the pallet hole at 2, so pulling open the large pallet *C*. The compressed air in the chamber *AA* now rushes into the chamber *BB*, and so into the primary motor *D*. This latter is promptly filled up, and automatically cuts off its supply by means of the pallet *E*, the residuum of air in the motor escaping through the open exhaust vent at *F*. The motor *D* now being unsupported, it promptly falls by reason of its weight, again allowing the air from the chamber *BB* to fill it up, with the same result as before. This motion continues for as long as the pallet *C* remains open. Upon putting the stop movement off at the console, the auxiliary motor *A* recovers, the previously explained movements are reversed, and the tremulant ceases to work.

The compartment *AA* is always full of compressed air, being in communication with the sound-board it is desired to affect.

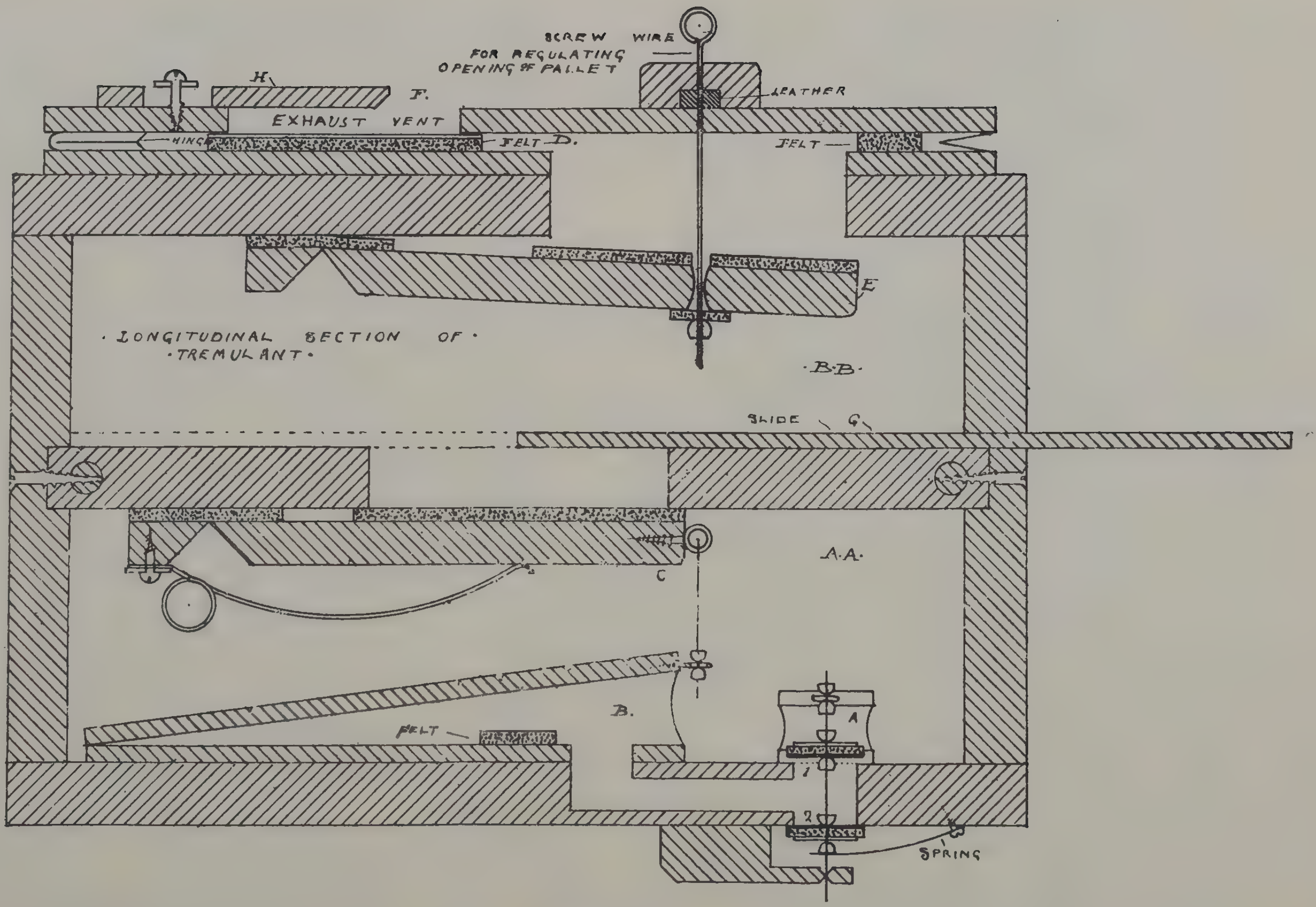


Plate 40

A FORM OF TREMULANT. (EXHAUST SYSTEM B[1])

The regulating wire passing through the pallet E forms a means of controlling the speed and effectiveness of the "beat," by increasing or decreasing the amplitude of the motor's vibration.

The slides G and H are for regulating the supply and exhaust of the air.

Another form of tremulant consists of a large strip of metal, vibrating in a frame, similar to a huge harmonium reed.* This is put in communication with the wind trunk by opening a pallet, with the result that it is set into vibration, affecting the air in the trunk in the same way as the motor tremulant does.

The most up-to-date form of tremulant hails from America Unlike the two previously-mentioned tremulants, which create a disturbance in the wind *before* it reaches the pipes, this latest form creates a disturbance in the wind *after* it leaves the pipes, thus acting directly upon the sound waves. †

It consists of a flat piece of wood or metal, disposed transversely and at an angle across the tiers of pipes, and rotated, by means of a suitable arrangement of motors, upon its longitudinal axis. The speed at which it is allowed to rotate determines the quickness of the beat.

To be as effective as the ordinary motor form of tremulant, the rotary tremolo, as it is usually termed, must be in an enclosed or restricted area.

For this reason, it is most effective when used in a *crescendo* box, as, for instance, a swell box. Also the beat, or tremulous effect, is most pronounced when the box is closed. The frequency of the beat is, of course, not affected, as the closing of the box does not increase the density of the air to any extent.

CONCUSSION BELLOWS

Concussion bellows are small bellows fitted with resilient springs in such a manner that they absorb any shock transmitted by the wind.

* Willis.

† This form of tremulant is often used in American organs.

They should only be fitted where made absolutely necessary, as otherwise they will probably have a reverse effect to that desired, and serve to accentuate a shock rather than absorb it. Sometimes these devices are fitted with a waste pallet, which opens when they are unduly agitated, this also counteracting the shock.* If they are fitted upon the same wind as a tremulant, their communication with the supply should be cut off by a pallet when the tremulant is set going, or the wind will be made unsteady and the legitimate effect of the tremulant spoiled.

Note to Plate 41.

The various drawings of organ parts lettered "Organ No. 1," when combined together, make up the instrument the end section of which is given upon Plate 41.

STANDARD MEASUREMENTS OF CONSOLE, PEDALS, ETC.

KEYS

The key frames—the wood frames bordering the bass and treble ends of the key-board—may be $2\frac{3}{4}$ inches in depth. The keys should not overlap—in this case, and where two or more manuals are employed—more than $1\frac{1}{2}$ inches. From the front of naturals to front of sharps, 2 inches. Length of naturals, $5\frac{1}{2}$; length of sharps, $3\frac{1}{2}$.

PEDALS

The pedals are best concave and radiating, and should be disposed centrally with the keys. The concave is an arc of a circle constructed with a radius of 8ft. Length of sharps, 6in. Distance from centre to centre of naturals, measured directly in front of the sharps. $2\frac{1}{2}$in.†

* T. C. Lewis

† This is the Willis pattern.

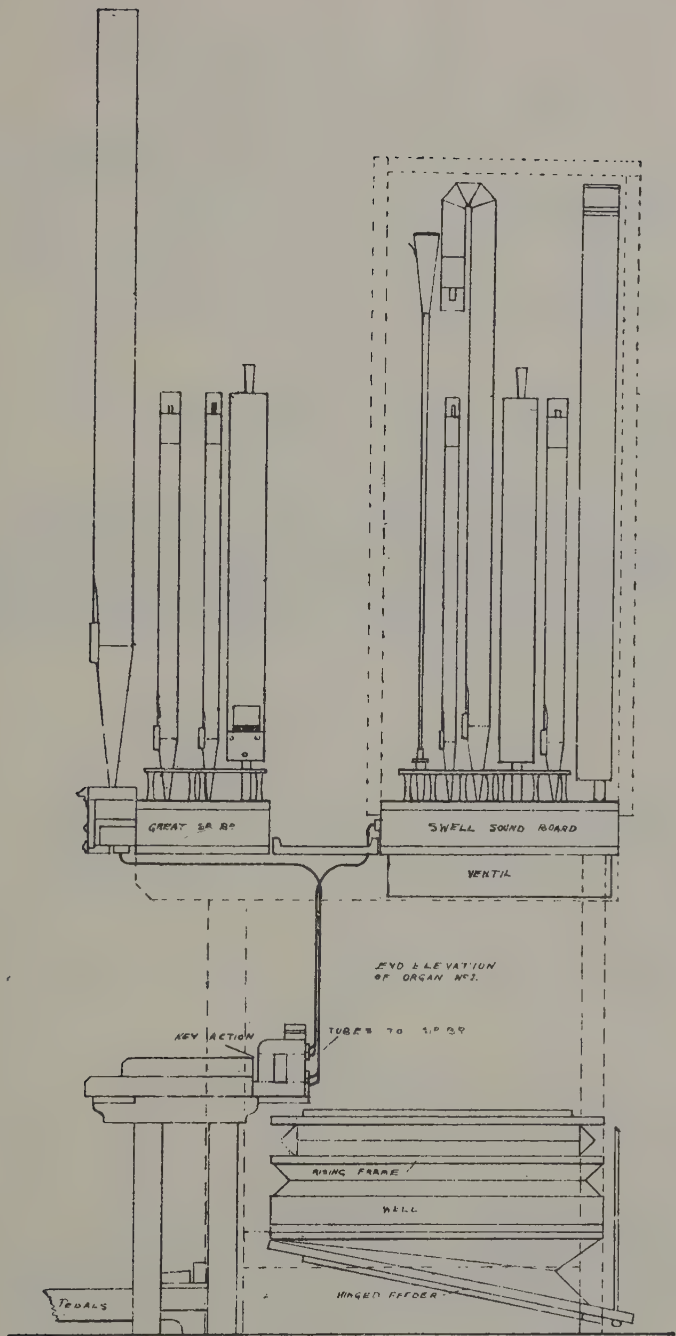


Plate 41

END ELEVATION OF A TWO MANUAL ORGAN WITH SWELL BOX. BUILDING FRAME SHOWN IN DOTTED LINES. ORGAN NO. 1. DETAILS OF THE CONSOLE OF THIS ORGAN WILL BE FOUND UPON PLATE 21, AND THOSE OF THE SOUND-BOARDS UPON PLATES 2 AND 3.

From the top of the middle natural on pedals to the top of middle key on the lowest manual, 2ft. 6½in. Distance in of the front of middle C sharp on pedals, determined by dropping a plumb-line from the front of a natural on the lowest manual, 10½ in.* For a four-manual instrument the distance may be increased to as much as 1ft. 2in.

The standard height to the top of organ stool, measured from the top of middle pedal, is 1ft. 9½in.

Strictly speaking, there are no standard measurements recognised by each and every organ builder throughout Great Britain, and the measurements approved and published by the College of Organists at various times have varied slightly. The latest ones are, we believe, included above. They are, of course, open to modification to suit individual organists.

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* This is for a three manual; for a two, 8½ ins.

CHAPTER V

ORGAN BLOWING

The four sources of power for organ blowing—Water—Pressure necessary for hydraulic engines—Why water power is the best—Electricity—Eccentric shafts and feeders—Fans —Worm gears—On gearing methods in general—A suggestion—Resistances, wire and water—Alternating current, fast and loose pulleys, and fans—On noise in blowing actions —The drawbacks of gas and petrol motors for organ blowing

POWER BLOWING INSTALLATIONS

WHERE it is possible to instal some form of motor for blowing an organ, after the first initial cost, it will be found the most economical, satisfactory and convenient method of overcoming a difficulty.

The sources of power available, placed in their order of merit are:

Water,
Electricity,
Gas,
Petrol.

Water is generally by far the most satisfactory source of power. Where there is a mean pressure of thirty pounds to the square inch, and the certainty of a constant supply, a hydraulic engine or engines form the nearest approach to the perfect blowing plant. They are noiseless and may, therefore, be used in the building and in direct connection to the instrument. Moreover, they are eminently reliable,

and need no attention beyond an occasional oiling. Another reason in their favour is that the water used is exactly proportional to the amount of work done. In no other form of blowing plant is there the same combination of good qualities.

Plate 6 shows a typical example of hydraulic blowing plant.

ELECTRICITY

There are two generally recognised methods of blowing organs by electricity. One is by a high speed fan, and the other by means of an eccentric shaft and feeders. Where the supply of current is *continuous* the eccentric shaft and feeder method is to be preferred, as it is much quieter than a fan. Plate 7 gives an example of a three throw eccentric shaft and feeders.

With this method it is customary to have a comparatively low speed motor, its motion being further reduced by being transmitted through a worm gear. Sometimes the worm gear, as it is expensive, is dispensed with and a series of pulleys connected by belts are employed to reduce the speed. In any case the principle is the same. A low speed motor, consequently of much greater size than would otherwise be necessary, and in addition a conglomeration of belts and pulleys or an expensive worm gear, the idea always being to use huge feeders moving at a very slow rate.

There is another method that may suggest itself to the reader, but which has been neglected by the vast majority, if not the entirety, of organ builders.* It is—that the same result is effected by employing a high speed and comparatively inexpensive motor in direct connection, without any intervening reducing gear, with small feeders.

In the first method, as we have stated, the feeders are large and

* This statement is rather in the nature of a libel. Almost every conceivable method of blowing organs has been tried, sometimes with satisfactory results, sometimes not. The fan blower is the most perfect mechanical means of adapting this idea. See footnote on page 110.

move very slowly; and in the second, the feeders are very small, making up for their lack of size by moving quickly.

The demand on the supply of wind in an organ is not, of course, equal at all times. At one time the motor will be required to run nearly up to top speed, and at another it will require to be reduced to almost a "crawl," according to the amount of wind in demand. To effect this, with a continuous current motor, some form of resistance, varying with the type of motor used, is introduced into circuit. This is either a wire or water resistance; in either case a connection is made to the top of the main bellows, on to the arm of the wire resistance, or, in the case of the water, on to a plunger which is suspended in an earthenware pot. When the bellows is full, the maximum amount of resistance is introduced and the motor revolves very slowly. Directly any quantity of wind is used, the bellows drops in a corresponding degree, cutting out so much resistance, with the result that the speed of the motor is increased, and the bellows is again filled. In fitting a wire resistance care must be exercised that the right amount of resistance is inserted at the right moment, otherwise the result will be most unsatisfactory. The fixing of all wire resistances in organ blowing is largely a matter of experiment, the correct result hardly ever being obtained at the onset. For this reason, whenever possible a water resistance is to be preferred. This is self-adjusting, and will, when correctly made, be found to give entire satisfaction. It should, however, be removed from where the vapour (which is evolved when the resistance is in use), will be likely to have a detrimental effect upon the leather work of the bellows.

Where the electric supply is alternating, it is not possible to vary the speed of the motor by a resistance. In this case there are two alternatives; either to have a crank and feeders with a fast and loose pulley, or to omit feeders and obtain the supply of air from a fan. Of the two, the eccentric and feeders is the least noisy, but the noise of a fan is counterbalanced by several advantages it has over the fast and loose pulley.

With alternating current, whether feeders or a fan be used, the motor always runs at top speed. In the case of the feeders, a belt drive is used, the belt being thrown on to the loose pulley when there is no demand on the supply of wind. In the fan, the superfluous air is simply compressed in the trunk connecting the fan to the bellows. After a certain degree of compression is reached, no more air can be passed through the fan, which continues unavailingly to revolve at top speed.

As a general rule, all electric-blowing installations should be away from the organ itself, as they are all more or less noisy. A high-speed motor, *when suitably geared for blowing*, produces more noise than does one at a low speed. Also, a belt drive is more noisy than a worm gear, and a fan than either.* Individual conditions prescribe the form of blowing installation to a great extent, but it is a matter in which the guidance of an expert is necessary.

GAS AND PETROL ENGINES

In all cases where gas or petrol engines are used, they must be placed at some considerable distance from the organ. They are generally used with an eccentric shaft and feeders, with a fast and loose pulley. They have many objections in common, being extremely noisy and "messy," and they are certainly not marvels of reliability. Added to this, they are not self-starting, and their need for constant attention renders their use, usually, only a last resort.

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* The rotary fan, or centrifugal fan as it is also called, is now much more perfect than when this was originally written. Owing to the high cost of water in some places, a fan is preferable to an hydraulic engine for the sake of economy, and preferable to a crank-shaft and feeders in cases where the supply of current is alternating, on grounds of efficiency.

CHAPTER VI

ORGAN PIPES

Kinds of pipes—Constructional details—Composition of pipe metal—Zinc—Proportionate cost of basses to remainder of pipes in a stop—Wood flue pipes—Free reeds and beating reeds—Constructional details of ordinary beating reed boot—Bodies, tubes, or resonators—Mitreing and hooding—Effect of dust on tone of reeds—Diaphones—Tremulant and valvular reed kinds—Production of sound from flue and reed pipes—Hermann Smith's theory—Full length, short length, and harmonic reed tubes

ORGAN pipes may be divided into two species, flue and reed pipes, with the possible acceptance of a third, diaphones.

Flue pipes are the oldest and simplest kind, and as they form the basis of any scheme of tone production in organs, in that sense they may be viewed as the most important. In modern organs of moderate size, reeds are included in the proportion of about one reed stop to five flue stops; in large organs the proportion might become as three is to ten, with a still greater proportion of reeds in organs on the grand scale.

Diaphones are comparatively innovations. The builder, Hope-Jones, introduced them into many of his instruments, but as they are used to produce volume of sound rather than distinctive quality, their value is determined and limited by this. Flue pipes and reeds are the staple sound producers.

Metal Flue Pipes —On Plate 42, Fig. 1, may be seen a section of a metal flue pipe with the names of the parts lettered upon it.

This kind of pipe has two main parts; the upper part, cylindrical, is called the body, the lower part is soldered on to the body, is conical

in shape, and called the foot. The foot is for the purpose of conveying wind under pressure to the mouth (or embouchure) to "sound" the pipe, and the body acts as a resonator.

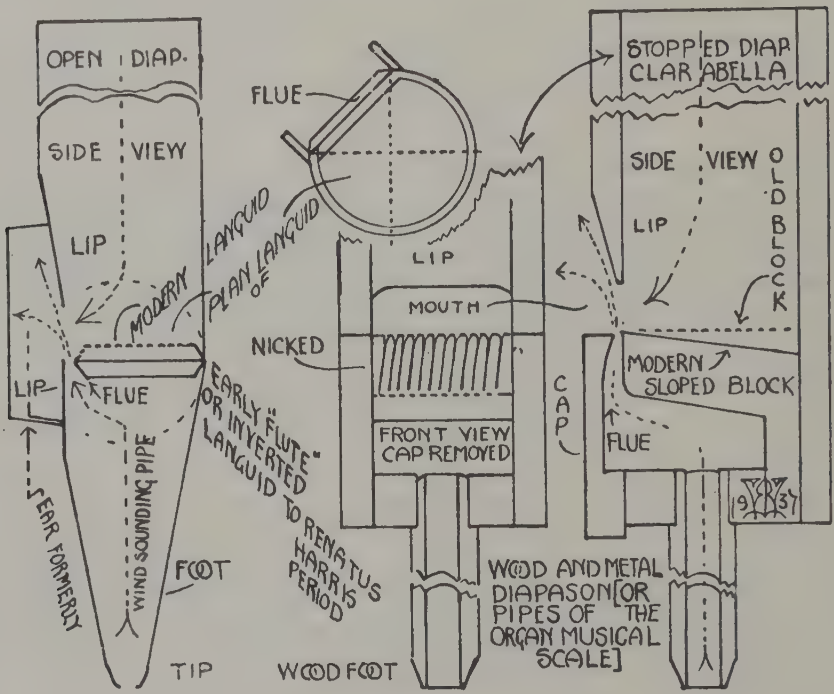

Plate 42

SECTIONS OF ORGAN PIPES

The details of the pipe are:

The Tip, which fits into a countersunk hole in the upper board of the sound-board is malleable; it may be closed up or opened out easily by means of instruments, thus admitting less or more wind into the foot. Except for one or two basses no flue pipes require the full pressure of wind available on the average organ. The tip therefore provides a ready means of perfectly adjusting wind pressure to scale: closing the tip reduces quantity and pressure of wind, with the reverse.

The LANGUID separates the body from the foot, permitting emission of air in a thin flat sheet through the flue. An inverted languid is shown on the diagram, Fig. 1. This form is sometimes used with Diapasons.* Usually the front edge of the languid slopes oppositely to that shown. The languid is soldered firmly in the pipe except at the flue, and may be raised or lowered to an extent prescribed by the ductility of the metal.

The FLUE is the space between the front of the languid and the bottom lip of a metal pipe. The extent to which this is open may be measured exactly by a wedge. By pressing the bottom lip in the flue is closed, and the reverse. The extent to which it is allowed to open has important effect on tone and speech.

The TOP LIP is made similarly to the bottom one, by smoothing the metal to a straight line at the mouth, this in the case of ordinary flue pipes. In the case of pipes visible in a front, the top and bottom lips are specially treated in decorative manner by giving definite shape to them. In such case the mouths may be either of the bay leaf or "French" form: with the first the top lip is in outline like an early English arch, above the mouth; and the French mouth may be compared to a Roman arch. The bottom lip with both is semicircular. In the case of zinc pipes, top and bottom lips are soldered on, and with the tip and tuning piece, are of pipe metal.

The distance of the edge of the upper lip from the edge of the bottom lip is known as the "cut up," and is of prime importance with regard to volume of tone and quality; and the angle of inclination inwards determines promptness or slowness, perfect or imperfect articulation of "speech" according to degree of inclination, which is variable according to the adjustment of flue, languid, wind pressure, and tone quality.

The EARS of a pipe project each side of the mouth at right angles. They are not required in all flue pipes, and are chiefly for the purpose

* This form of languid was invented by Mr. Herbert Norman.

of assisting speech, and ensuring steadiness—i.e., invariable pitch and volume of tone. The extent to which ears project in front of the mouth is of most import with regard to their effect.

From the old way of making Gambas with "bell" tops, arose the necessity of tuning them by means of their ears, which were made to project abnormally. By bending the ears over towards the mouth, the pitch was flattened, with the reverse. This method of tuning is defective because alterations in pitch are accompanied by difference in tone quality and volume.

Beards are used with some flue pipes. A beard may be round, oval, or infrequently rectangular in section, and is fitted exactly between the ears in front of the mouth. It has chief effect on promptness of speech and quality, and has a flattening tendency on pitch. Beards are used principally with Gambas.

"Metal."—It is apparent that the tubular structure of metal pipes is due to the properties of the material of which they are made. "Metal" in organ builders' phraseology applied to pipes, means an alloy of tin and lead. The higher the percentage of tin the better the metal is to work up to a composition of about equal portions of both. The large bright spots on the surface of the true "spotted metal"* indicate an alloy of nearly equal quantities of tin and lead. With such a composition the solder fuses readily with the metal Pure tin is not sufficiently workable to be used. A composition of tin and lead in which there is twenty-five to thirty per cent tin makes a good plain metal for ordinary † work. The treble portion of any stop from Middle C is best made of spotted metal.

Pipes of almost pure lead are used in cheap work. When of any size these gradually settle down and lose shape and adjustment at the mouths and feet, with consequent loss of tone.

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* "Pepper and salt" spotting begins when the proportion of tin is a little more than one third.

† Most "ordinary" work encountered, however, is not so rich as this in tin.

In the ordinary way, zinc is used at the present time for the bottom octave of large scaled stops by most builders, but even in such cases the parts requiring adjustment must be of pipe metal, soldered on, and therefore such adjustments are not so easily made as in the case of purely metal pipes; and in the case of the languid, are made at some risk of breaking the joint. At the same time it should be considered that, allowing for considerable fluctuation in the price of zinc as compared to pipe metal, the lowest twelve notes of any stop cost at least as much to make, even when of zinc, as all the rest of the pipes in the stop together, and if a stop is of good metal throughout, the twelve bass notes might easily cost twice as much as the remaining forty-nine pipes.

Wood Flue Pipes.—(See page 137 for further remarks concerning the effect of material on tone.)

On Plate 42, Fig. 2, may be seen a section of a wood flue pipe. The principal difference between wood and metal pipes is one of structure consequent upon the properties of these materials. Most wood flue pipes are rectangular in cross section, or, infrequently, triangular, as these shapes may readily be constructed in wood.

A wood flue pipe has four main parts:

The foot, block, cap and body.

The detailed structure of these parts is:

The tip of the foot is slightly pointed to fit in a hole bored in the upper board of the sound-board. To regulate the supply of wind, thin pieces of wood are here inserted (for the same purpose that the tip of a metal pipe is closed upon its centre). The top part of the foot has a shoulder, and fits into a hole bored in the block.

The block of a pipe is made of hardwood, usually mahogany, or in the case of a large pipe, it may be built up of several thicknesses of soft wood and faced with hardwood* for the purpose of taking

* The term "hardwood facings" should include cap, block, and in the case of small pipes, the front as well. Wood pipes endure longer, and present a better appearance if they are either painted, varnished, or coated with shellac. They should be sized internally and preferably banded with linen at the top if stopped.

"knicks.' The shape of the windway varies slightly according to the quality of tone desired. The top of the block retreats from the mouth at an angle, more or less acute, according to stop. This angle imparts steadiness of tone.

The cap should be of hardwood, screwed on to the block without glue, so it is removable. It is hollowed out on the inside and so forms the flue. If the flue is filed too much, this is rectified by planing down the inner surface of the cap. In wood pipes the top of the block represents the languid and this is, of course, fixed and unalterable by ordinary methods. A compensation to this is provided in the cap; lifting the cap so that the top edge is moved towards the level of the top of the block, is equivalent to lowering the languid of a metal pipe, with the reverse.

The lip of a wood flue pipe, with small work, is continuous with the body, and in such cases the grain runs at right angles to the edge of the lip, which is made by chiselling the wood down as shown on the diagram, Fig. 2. Chiselling from the outside produces an ordinary lip, as shown; chiselling from the inside produces an inverted lip, the difference being in this case that the angle of the lip is on the inside surface of the front of the pipe. An inverted lip must therefore be made before a pipe is glued together.

With large pipes, in particular, those below the 8ft. length, the top lip is made separately from the front of a pipe, with some form of air tight joint. In this case the grain runs across the pipe, parallel with the edge of the lip. This is done for strength and convenience of working.

Stopped flue pipes may be of wood or metal. With wood pipes the stoppers are rectangular pieces of wood, covered in leather, and provided with a handle. In large work they may be built up of several thicknesses of wood, two at least, so that the grain runs in two directions at right angles to counteract shrinkage.

With metal pipes, stoppers may be of turned wood covered in

leather, or of cork covered in the same way. In some cases metal caps fit over the ends of the pipes, made air tight with leather.

Stoppers are either blackleaded or greased that they may be moved up and down for tuning.

Tuning Clips—The tops of bass open flue pipes are fitted with some form of tuning device. The best arrangement is a tuning clip sprung on so that it grips the end of the pipe. With Gambas this clip reveals a slot as it is tapped down, but for pure Diapason tone, slots should be avoided. Stops of 4ft. tone and upwards are usually without tuning clips, as these clips do not allow of the delicate adjustment necessary for tuning notes of high pitch.

Reeds—In the organ reeds are represented by the two kinds, free reeds and beating reeds.

Free reeds are of the construction used in harmoniums, a metal tongue vibrating in a frame.

Beating reeds are usually arranged over a triangular aperture in a brass shallot so that they vibrate against it. Beating reeds are therefore restricted in one direction in the amplitude of their vibratory arc by the shallot, but free reeds not at all in this way. The amplitude of vibration of a beating reed is therefore as the curve of the tongue, and by this power and tone quality are within limits controllable. Free reeds are not so adaptable and depend more upon the shape and scale of resonators for their tone quality. The plasticity of beating reeds in the respect mentioned, renders them more suitable for general purposes in pipe organs, and free reeds are usually only used in large organs where the possibilities of beating reeds have been utilised to the borderland of exhaustion.

The resonators in ordinary reed work are of pipe metal, but they may be in some cases of wood. The "boots" are generally of pipe metal, tongues and shallots of brass, but not without exception.

Below Tenor C of the 8ft. standard reeds are usually made for convenience of handling in two parts: body and socket. In this way the reed tongue and parts necessary for holding it in position and tun-

ing, are easily detachable *en masse* from the body. Plate 43 illustrates a bass reed of this kind, which is referred to by organ builders as a "boot."

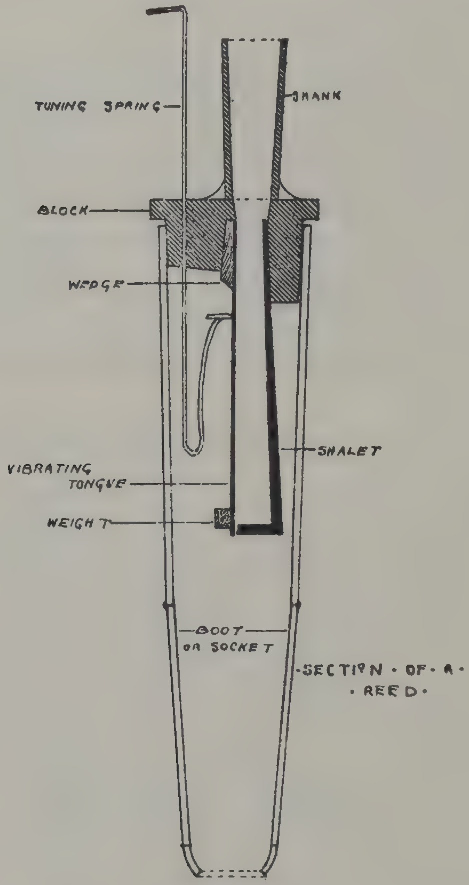

Plate 43
SECTION OF A REED WITHOUT THE TUBE OR RESONATOR

With small work bodies are soldered on to the blocks, and the blocks rest in feet.

The constructional details of the usual organ reed, as illustrated are :

The block is of lead, tapers slightly to fit into the foot, from which it may be detached. The *shallot* fits into a hole in the block, the

tongue being held against the shallot by a wooden *wedge* which secures tongue and shallot firmly in position in the block. By drawing out the wedge with a knife, tongue and shallot may be removed. A wire tuning *spring* is braced against the tongue, and a crook provides a means of tuning. Tapping up the spring with a tuning "knife" lengthens the vibratory length of the tongue and flattens its pitch, with the reverse. The slightly tapering foot with rounded tip rests in a countersunk hole in the sound-board.

In order to avoid reducing pressure, the wind hole at the tip of the foot is in most cases kept large. With long "boots" reeds are liable to be "slow in going off," and boots may sometimes act as resonators to the complete ruination of tone. A small exhaust hole is therefore often pierced in the boot, with generally, the satisfactory result of overcoming both defects. Henry Willis introduced extremely short boots which are a more perfect means of accomplishing the same thing. With this treatment rack boards for the reeds have to be closer to upper boards. The advantages of this, additional to the ones mentioned are : *(a)* no reduction in wind pressure because no exhaust hole; *(b)* reeds are right on their supply, and speak promptly. Piercing holes in reed boots has a precisely opposite tendency to *(a)* and *(b)*.

Bodies, *tubes* or *resonators* of reeds, as they are variably called, when long, may be "mitred" at their slenderest parts, or when short and of suitable shape, may be mitred at right angles at their tops. Mitreing is a term familiar to woodworkers, and indicates in the case of organ pipes a process of making angular cuts in them so that a number of pieces are cut out and joined up again in a sort of loop—an angular loop instead of a curved one as in a bugle : or it may be according to the number of cuts, that the top portion merely is thus placed at a right angle. This structure prevents dirt, etc., falling down bodies on to reeds, and where the complete "loop" is made, strengthens the body, so preventing bending and distortion liable to occur to long slender tubes. Where tops only are thus treated the process is known as "hooding."

Unenclosed reeds should certainly be treated in one of these ways, as the exclusion of dust particles and dirt preserves, to a great extent, pristine tone quality unaltered. All dust cannot be excluded, by any means, and in consequence a slow but sure deterioration of tone takes place with all reeds. A sticky coating of fine dust particles becomes deposited on tongues and shallots, a sort of sediment from the air stream passing through them. In large towns after two or three years' usage, examination of reed tongues reveals first traces of this precipitation, and after from seven to ten years comes perceptible coarsening of tone. Careful cleaning will then resuscitate tone. Tuning tends to alter the curve of a thin tongue, with deleterious effect after many repetitions.

Flue pipes are also adversely affected by dust, which settles thickly in course of time on languids, and coats over lips and fills up the knicking. The idea of straining air before it enters pipes has been applied by putting muslin under the feet, and proves so effectual in practice that in very quick time such strainers become impregnated with dust particles, and notes become dumb; so that the last case is worse than the first.

Nearly all reeds need supporting "stays" to which it is preferable to tie them by means of tapes, "hooks" being objectionable, as vibration of tubes against stays is possible, besides a difficulty of replacing tubes in position in the event of it being necessary to clean or adjust a tongue occasionally when all pipes are *in situ*.

Free reeds are not so readily fixed in position in metal boots, as beating reeds, and for this reason wood may be found substituted for metal. In such case, the block is represented by a rectangular piece of hardwood, and the reed frame may be screwed against a slot in this. A means of tuning has to be provided in somewhat similar fashion to that adopted with beating reeds, but the ordinary spring tuning wire is obviously inapplicable, as it is necessary that the reed be gripped back and front.

DIAPHONES

The name "diaphone" was applied by Hope-Jones to two kinds of sound producer which he perfected, represented on Plate 44.

Fig. 1 consists of a disc pallet at the end of a spring free to vibrate against a hole in a hardwood block which communicates with

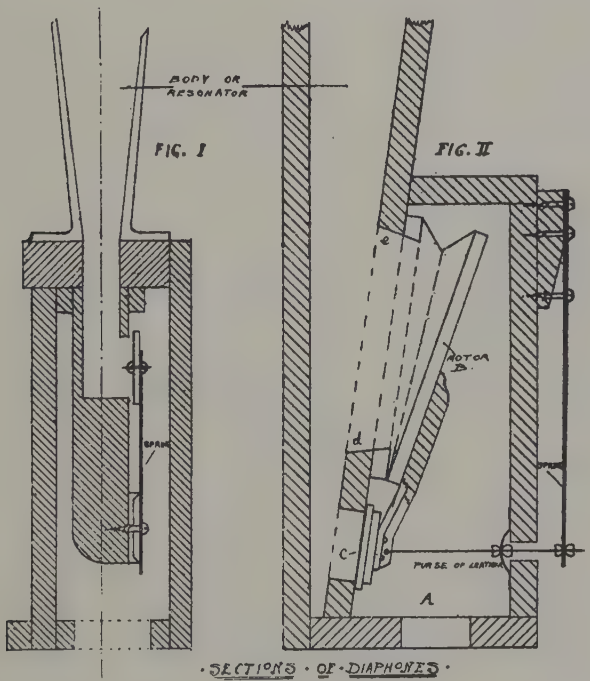

Plate 44
SECTIONS OF TWO FORMS OF DIAPHONE

a resonator. The way in which compressed air acts on this disc valve is exactly the same to what takes place with an ordinary beating reed —in fact, this diaphone may sometimes be referred to as a "valvular reed." This form is tuned by the spring, and resonators are provided with a means of regulating power in the same way as ordinary reeds.

The working of Fig. 2 is:

Compressed air enters through the hole at A, collapses motor B, and pallet C uncovers the circular pallet hole, whereupon compressed air is admitted into the resonator. When this compressed air reaches *de*, pressure inside and outside motor B is nearly equal, and pressure of air on pallet C, assisted by the tension of the flat spring, brings pallet C against its seat, closed. The apparatus is now ready for another "vibration," and the cycle of movement described continues as long as wind is supplied at A. The number of these vibrations in relation to time, as in the case of an ordinary reed, determines pitch. The pitch is altered, for tuning, by some device which has the effect of *(a)* lengthening a resonator, or, *(b)* the reverse, with consequent *(a)* flattening, or *(b)* sharpening

The satisfactory working of motor (or "tremulant") diaphones depends to a great extent upon adjustment of springs, as also does tone quality. The imperfection here is, that an adjustment for tone may prove unreliable for working. In consequence necessary irregularity of tone, or reliability must be sacrificed.

With diaphones power and tone quality is also variable by scale and shape of resonators.

There is another form of Hope-Jones diaphone in which instead of a single disc valve operated by a motor (as illustrated Plate 44, Fig. 2), two valves are used in somewhat similar fashion to the familiar double pallets used in pneumatic actions. The idea of this is to gain power, but the gain is not, however, twofold. Still another kind produced experimentally, consists in the substitution of a roller valve for a disc pallet, i.e., a soft piece of leather on a small roller which unrolls over a hole, like the inversion of a window blind on a small scale supposing the edge of the blind fixed, and the blind capable of being *unrolled* over an aperture.

An experiment with the valvular reed type of diaphone was made by Messrs. Blackett and Howden, of Newcastle, in 1888.

The diaphonic horn, or valvular reed, or diaphonic reed, was patented by Robert Hope-Jones in 1897, as an improvement on his previous inventions of the "tremulant" kind, in which motors were used in conjunction with valves.

THE PRODUCTION OF SOUND FROM FLUE AND REED PIPES

In flue pipes, as demonstrated by Cavaille-Coll in 1840 ("Etudes Experimentales"), and independently by Hermann Smith in 1865, and Herr Sonreck, of Cologne, in 1876, sound is produced by a free reed of air, or "aero plastic reed." (*Vide* J. I. Wedgwood's "Dictionary of Organ Stops.")

The following two paragraphs (from "Sound in the Organ and in the Orchestra," Hermann Smith) convey but an imperfect idea of the completeness of Hermann Smith's theory, but students will find it fully amplified in the book mentioned. It is much more satisfactory than the Helmholtz-Tyndall explanation (" . . . . the proper pulse of this flutter is converted by the resonance of the pipe above into a musical sound."—"Sound," Tyndall, 1875); and is opposed to this and similar text-book theories, which speak of the issuing air from the flue being split against the upper lip of the pipe.

*"Flue pipes are actuated by a *stream reed*; this stream of wind passes over the mouth, not entering the pipe or striking the lip; the *velocity of transit* in emission is converted into *velocity of vibration*, or to and fro motion; and the stream becomes a reed in mechanical motion."

And again:

"The work of the stream reed is specifically to abstract; rarefaction ensues on abstraction, condensation correlates therewith, and the result is vibration."

From this it appears that all organ pipes are "reeds"; in the flue

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* Hermann Smith.

pipe the reed is of "viewless wind," and in the so-called reed variety the reed is tangibly and visibly a brass tongue.

The main factors which determine the pitch of a sound produced from a flue pipe are:

Length, scale, shape, the "cut up," diameter of hole in the foot, and wind pressure.

Further, this catalogue might include ears, beard, adjustment of languid and flue, all of which affect pitch. Any adjustment or provision necessary in the interest of tone quality, must be compensated for by a variation in length to ensure conformity to the standard of pitch.

The study of the cause of sound in flue and reed pipes resolves into problems in mechanics very similar to the study of pneumatic actions. Henry Willis utilised a huge free reed tongue about 1ft. long by 2½in. wide as a tremulant, and a diaphone invented by Hope-Jones produced sound through the rapid movement of a motor working a valve. In these instances we have a reed acting in the capacity of a pneumatic action, and a pneumatic action acting in the capacity of a reed.

By interrupting the continuity of a stream of air admitted to a resonator, a reed tongue causes an alternation between *(a)* a high pressure above the normal atmosphere (high, according to the wind pressure the reed "stands" on) and a pressure *(b)* lower than the normal atmosphere; *(b)* is low in proportion as *(a)* is high. In everyday phraseology *(a)* is pressure and *(b)* is "suction." This may be expressed in terms of the scientists as *(a)* condensation, and *(b)* rarefaction of air—i.e., sound (". . . a sonorous wave consists of two portions, in the one of which the air is more dense, and in the other of which it is less dense than usual. A condensation and a rarefaction, then, are the two constituents of a wave of sound"—"Sound" (Tyndall).

Readers interested in the minutiæ of the subject will find an analysis of a vibration of a reed tongue in Hermann Smith's book

previously mentioned in connection with the æroplastic reed theory of the cause of sound in a flue pipe. Also the result of M. Weber's investigations into the relation between pipe and reed. The relation of pipe and reed is a reciprocal interaction. A reed gives a cracked unmusical note minus resonator, which is added to enhance power and greatly to determine tone quality. Shortening the length of resonators deflects pitch to some modified extent only. By varying the length of reed, pitch is ruled absolutely with invariable length of resonator, but an increase in length of resonator must be compensated for by shortening the vibrating length of the reed tongue, i.e., by tuning sharp in order to conform the pitch to standard. The vibrating length of the reed tongue may thus be said to rule pitch. This is exemplified by a comparison of an Oboe, Clarinet and Vox Humana, supposing them to be tuned to a common pitch, in unison, and standing on the same wind pressure. All these would have approximately the same length of reed tongue, but the resonator of the Clarinet would be about two-thirds as long as the Oboe, and the Vox Humana about half the length of the Clarinet—three very different resonator lengths for the same note. Reed tongues "approximately" the same length means that the slight differences bear no obvious pro ratio value to differences in resonator length.

In this way resonators for reeds come under three headings: full length, short length, and double length or harmonic.

A full length body means one in which the enclosed air column has a vibratory rate equal to that of the reed tongue, and is therefore in synchrony with the latter.

A short length body signifies the abrogation of the synchronous ("full") length in favour of a shorter length determined by precedent and experience. The idea is to obtain a thin tone quality, lacking foundation, as the prime tone of the need is not perfectly reinforced. Short length bodies may sometimes be more definitely defined as three quarter or half unison length.

Double length or harmonic reeds are provided with bodies twice

synchronous length. By this means a peculiar clear tone results, and less of the ordinary tendency of deviation from the flue work in pitch.

Chorus reeds are now generally made harmonic, or rather, partly harmonic, as the effect of harmonic bodies is not so obviously beneficial* in the basses of chorus reeds. For this reason basses are of true length, the double length bodies commencing at Tenor C. Again the extra length may be added only to the Treble octave to elude the well-known propensity of that register to go out of tune. Extra length does not imply merely increased power, but increased purity.

Reeds of full length are liable to "fly off" their correct pitch to an overtone under certain conditions. This danger is obviated if the following treatment be applied:

Place a hand over the top of the body as the reed sounds. If, under this test, a reed "flies off," the tongue may be curved more open, but as it is undesirable, usually, to interfere with tongues after a stop is "finished," a little may be cut off the body at the top. After this it will be necessary to tune by knocking the spring up, so lengthening the tongue.

Resonators for reeds may variably be called bodies or tubes We have referred to "reed pipes," in this chapter when comparing reed resonators with flue pipes. "Tongues" are also referred to as reed tongues. "Reed work," and "reeds" have a general significance as collective names for all stops in which sound is produced by vibrating tongues in conjunction with resonators. The "tongue" is really the "reed."

"Full length," "true length," and "unison length" have the same meaning.

In order to avoid repetition, further information concerning reeds and flue pipes is held over to the next chapter.

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* Nor so necessary for the purpose of keeping them in tune. Owing to the delicacy and sensitiveness to thermal changes of true length treble reeds, most builders utilise flue pipes for the extreme of the treble compass, save with harmonic reeds.

CHAPTER VII

THE PRODUCTION OF TONE IN THE ORGAN

Introductory—The harmonic series—Effects of overtones on timbre—Voicing—Wind pressure—Wind pressures used in the organ and in the orchestra—Effect of scale on tone—Width and height of mouth—The "cut up"—Nicking—Effect on tone of material—The Diapason and Gamba types—Flutes—Overblown Flute—Cavaille-Coll's Flute Harmonique—The Clarabella (Bishop)—The pierced Gedeckt—Regulating—To "louden" flue pipes—To "soften" flue pipes—The speech of flue pipes—Defects, "too quick" and "too slow"—Windiness and unsteadiness of tone—Reed voicing—Pressures used—Tongues, thick and weighted—The curve of reed tongues—Regulating reeds—List of generally used stops

INTRODUCTORY

ACCORDING to scientific theory, the difference between noise and musical sound is, that the latter has perfect periodicity of vibration whilst the former has not. We are all aware of this, and acquainted with the fact that a definite number of vibrations, perfectly periodic, per unit of time, produce a musical note of definite pitch: further, that the amplitude of these vibrations (or two and fro swing of the air) determines the power of the note. This represents a simple musical sound, a certain number of vibrations of a certain amplitude per unit of time; in consequence, a sound of definite pitch and power. For convenience, the unit of time selected by investigators is the second.

A third characteristic of sound there is, variously termed quality, tone quality, tone colour, timbre, etc., by which flute, violin, bassoon, are not confounded. This arises from the fact that all musical sounds

are compound and cannot be truly represented by one vibratory rate. In the organ the nearest approach to a simple musical sound is that produced from a Stopped Diapason. All musical sounds are, then, compound.

In addition to the vibrations of the lowest sound producible from an organ pipe are superimposed a series of tones whose rates of vibration are multiples of the lowest in their sequential order. These tones were called "upper partial tones" by Helmholtz, the whole series being termed partials, of which the lowest in pitch was number one. Helmholtz first discovered the influence of these upper partial tones on timbre. The first partial is sometimes referred to as the prime, ground, or fundamental tone, and the vibratory rate of the prime determines pitch; whilst the power and number of the upper partials influence tone quality. We publish herewith a table of the harmonic series, as these upper partials are also called.* With any open pipe,

	Harmonic Series		Vibrations. Harmonic Scale	Vibrations. Tempered Scale
Prime tone vib. 64	16	C^5 —	1024	1024
16	15*	—	960	966·53
384	14*	b♭ —	896	912·28
64	13*	—	832	812·75
1024	12	g —	768	767·13
Intervals.	11*	—	704	724·08
From 9 to 10. a minor tone	10	e —	640	645·08
From 8 to 9, a major tone	9	d —	576	574·7
From 7 to 8, a (wide tone)	8	C^4—	512	512
From 6 to 7 (harmonic seventh)	7*	b♭—	448	456·14
From 5 to 6, a minor third	6	g —	384	383·57
From 4 to 5, a major third	5	e —	320	322·54
From 3 to 4, a fourth	4	C^3—	256	256
From 2 to 3, a fifth	3	g —	192	191·78
From 1 to 2, the Octave	2	C —	128	128
Prime Tone	1	C^1—	64	64

* From Hermann Smith's "Modern Organ Tuning"

the second partial—which is the first harmonic—has a vibratory rate twice that of the prime; the third partial, three times that of the prime; and so on. With stopped pipes only the odd numbered partials are present. It will be noticed that the vibratory rates of harmonics, except necessarily the octave, super octave, etc., do not correspond with our musical scale; whilst the seventh, eleventh, thirteenth, fourteenth and fifteenth partials are discordant. In the order of ascent from harmonic to harmonic the intervals between them continuously lessen and never repeat. If this table were extended sufficiently musical chaos would therefore finally result. By overblowing a pipe with a succession of blasts of increasing strength, a number of these harmonics may be isolated one after another.

When the fundamental note is accompanied by the lower harmonics, 2, 3, 4, etc., it acquires a broad, grave character, as with the Open Diapason. If the higher and dissonant harmonics dominate, tone becomes thin, reedy and keen, as with a Gamba; or, according to range and intensity, as with the Trumpet. Reeds and Gambas are richest in harmonics. A note unaccompanied by harmonics may be ponderous and pervading, or if not low in pitch, sweet in tone, but is without musical value except in combination with sounds of richer timbre; but it by no means follows that the musical value of sound is commensurate to its complexity;* rather, according to the scientific theory of consonance, to its simplicity: for the simpler the ratio between the number of vibrations per second of any two sounds, the more perfect the consonance.

VOICING

Voicing may be defined as the art (or process, if preferred) of obtaining perfect articulation of desired qualities of tone from organ pipes. Although they are not entirely separable, voicing has two

* "Musical value" in combination with other sounds, that is; yet a sound may have a value other than a combinative one, i.e., a contrasting one.

aspects: the obtaining of tone, and the perfect articulation of it. A pipe must be given a voice of characteristic timbre, without defects of speech; for a pipe may have a voice of good quality, yet be afflicted with a stammering impediment in speech: or it may speak promptly and perfectly, yet have a voice of poor quality. Adjustments and proportions of pipes necessary for some tone qualities require special direction of effort towards overcoming concomitant defects of speech. The classic example of this is the Gamba, which, before the provision of a "beard," was extremely slow in speaking, even when a comparatively mild degree of pungency was aimed at: although beards have, apart from effect on speech, decided effect on tone also.

As the voicer's work begins where the pipe maker's ends, he is not directly concerned with questions of scale; but exigencies of subject make it preferable to deal broadly with it under one heading.

Following the convenient and usual classification of organ pipes they may be arranged as:

Diapasons: including Principal, Fifteenth, etc., Mutation work and Mixtures.

Gambas producing a string tone.

Flutes, including the Gedeckt family.

All these are flue pipes, of wood or metal. The other kind of organ pipes, reeds, cannot be classified on the same basis as flue pipes with any advantage.

In this way flue pipes are arranged according to tone quality, of necessity broadly, as there is no standard Diapason, Gamba, or Flute tone.

The factors* which determine the quality of tone produced by a

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* Pitch and timbre are ultimately reducible to a common basis. All the factors named above may be considered as *(a)* energy and *(b)* work.

(a) Energy is the equivalent of the weight supported by the organ reservoir, measurable on the gauge as wind pressure.

(b) Work is the amount of resistance encountered by the current of air in passing through the bore and flue, etc., and in bridging the gap at the mouth, and the quantity of air to be set into vibration. The energy of the air is lessened at the bore, etc., before the real task of setting the air column enclosed in a pipe into vibration begins.

"The production of harmonics in organ pipes is due to an excess of energy in the

flue pipe are: (1) wind pressure; (2) diameter in proportion to length; (3) shape, (4) width of mouth; (5) height of mouth; (6) depth and number of nicks; (7) material.

The adjustment of top and bottom lip and languid, and diameter of bore in the foot (which modifies the wind pressure upon which a pipe stands), must be made to certain definite requirements according to the kind of pipe, Diapason, Gamba, or Flute. Once a pipe has been voiced with a certain bore, this cannot be altered without affecting pitch, tone quality, and power. All these factors, great and small, exert a reciprocal interaction upon each other, and an indefinite number of combinations of scale, width and height of mouth, etc., make possible a graduation of timbre from a simple fundamental note to a fluty Tibia Major quality, from thence to a Clarabella tone, Diapason tone, through the Geigen family to the String Gamba, and from that to the Viole d'Orchestre keenness: this represents a sort of unbroken spectrum of tone quality of which the primary colours are, Flute, Diapason and Gamba.

Most organ stops have a known history, the old ones and some of the modern ones, a traceable evolution, and except with a few so rash as to presume to be in their teens, a traditional place and usage in the grand chorus of organ voices. Schemes of organ tone—(the treatment of Swell, Great, Choir and Pedal departments)—are based more

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exciting agent beyond that necessary to cause a ground tone to exist, one may say, barely to exist."—"Modern Organ Tuning" (Hermann Smith).

Thus, according to this statement, if a = energy, and b = amount appropriated by the prime, $a—b$ = amount available for harmonics. Thus the greater the energy the greater the number of harmonics. This supposes b as constant.

If, on the other hand, b is increased, and a remains constant, the available surplus for harmonics becomes less. Thus, by increasing the scale of a pipe, the quantity of contained air becomes more, and more energy is required to produce both prime and harmonics; and if in this case, more energy is not forthcoming, any surplus previously available becomes less or is entirely absorbed by the prime.

This illustrates the effect of scale on timbre, particularly in the case of flue pipes. In detail reeds are a different proposition, but ultimately stand on a common basis with flue pipes, reduced to their lowest terms of *energy* and *work*.

on tradition and convention rather than principle; are, in fact, more artistic than scientific. The treatment of organ stops with regard to scaling and voicing is likewise traditional and empirical rather than scientific.

With the exception of the Gemshorn shape, and its inversion, that of the Dolce, all flue pipes are now made cylindrical if of metal; rectangular in cross section if of wood. Considerations of shape do not therefore call for more than this notice as far as concerns flue pipes.

WIND PRESSURE AND SCALE

These two are in effect modifiable by each other, and by the factors already enumerated, but they form the basis of tone production.

One inch of water supported in an organ builder's wind gauge (an anemometer, or difference manometer) is the equivalent in weight per square foot on the bellows top, of 5 lbs. 3 ozs.: this includes also, weight of woodwork.

The wind pressure in old organs was seldom higher than 2¾ins. Beside, in the absence of power blowing installations, the difficulty of blowing, was the pallet resistance inseparable from any wind pressure, with consequent result on touch. For organs of more than a few stops to be playable under ancient conditions, a low wind pressure was essential. Early builders had to choose between small pallets, which allowed but few stops at a time to be played, or low wind pressure, and English builders selected the latter alternative. Such conditions favoured the Diapason, which in the hands of many famous builders became a thing of great beauty; whilst Mixtures became a necessity to supply the lack of high harmonic development.

The lowest pressure now usual is 3½ins., and in large organs for special reed stops, pressures from 20ins. to 25ins. have been used. Most organs of any pretension have now several pressures. This necessitates a separate reservoir for each pressure and divided sound-

boards. Diapason work, as already mentioned, is best suited by moderate, and reeds, in some instances, by high pressure.

Comparison with the orchestra reveals that high pressure for reeds is not exceptional to the organ. From the lowest to the highest note produced by the oboe of the orchestra, pressure ranges from 9ins. to 17ins.; with the horn, 5ins. to 27ins.; with the trumpet, from 12ins. to 33ins.; with the euphonium, 3ins. to 40ins.,* in which the highest pressure is attained.

With organ flue-pipes, decrease in length and diameter is accompanied by decrease in bore of the wind hole in the sound-board and in the foot of a pipe; therefore wind pressure is highest for the pipe lowest in pitch, and lowest for the pipe highest in pitch, owing to the well-known fact that wind loses pressure by friction the more the orifice through which it passes becomes restricted. Although wind pressure thus varies between pipe and pipe in a stop, it does so in proportion to scale and cut up, for the reason that as scale and length decrease, less energy, represented by wind pressure, is required to produce sound; otherwise, such energy unmodified would find an outlet in an increased number of overtones, and difference therefrom upon timbre;† or in completely overblowing the greater part of a stop.

The process of finely graduating wind pressure between pipe and pipe is known as "regulating," and ultimately depends upon the ear in obtaining uniformity of power throughout a stop: with pipes correctly scaled and voiced to that end, uniformity of timbre throughout the compass of a stop is correlative with uniformity of power; reeds, it is perhaps advisable to mention here, are not regulated in the same way as flue pipes.

In considering wind pressure, it should be remembered that there is a limit to the pressure any flue pipe will take without overblowing. As the limit is neared coarseness of tone becomes evident. With

* From a table experimentally compiled by Dr. Stone.

† See footnote, page 130.

unbearded pipes, the limit is defined by scale and cut up: the smaller the scale the more exactly must wind pressure be adjusted to requirements of speech, and the lower it must be. As a consequence, small scaled, unbearded pipes have no great amplitude of vibration, and must necessarily be quiet in tone: and the latitude allowed by their large scale is a temptation often succumbed to in allowing Diapasons to have too much wind that they may be bold and telling, but withal, coarse.

Combined with suitable wind pressure, large scale produces depth and volume, power and pervading quality of tone.

Small scales have an opposite tendency, and impart more decided colouring; more acute and intense timbre; brilliance, and the extreme of brilliance, string tone. But small scaled stops always lack dignity and grandeur.

The scale of a pipe, which, as already intimated, is its diameter, is given in inches. An organ builder refers to a "6in. Open Diapason," meaning thereby that the lowest pipe in a stop of that name has a diameter of that number of inches. As scaling is systematic—for instance, large scales may halve at the seventeenth note—the scale of the lowest note fixes the dimensions of the remainder of the pipes in a stop. Such a graduation in scale as that mentioned is impossible in some instances, as it might result in the Treble portion of some stops being impractically small. In such cases the graduation in diameter between pipe and pipe becomes little, as with a Viole d'Orchestre and Clarinet: in the case of the former the slight graduation is a necessity, in the latter deliberate intention. Whatever the scale of a stop, diameters of CC, Tenor C and Middle C would indicate it, but in most cases the diameter of one pipe is sufficient.

With wood pipes the measurement across the mouth is generally indication enough for those versed in technicalities; for exactness, the inside dimensions, which are the depth and width of the block. The mouths of wood pipes are cut the entire width of the body, minus the

thickness of the sides, and may be upon a wide or narrow side of rectangularly constructed specimens, according to tone quality desired.

The mouths of metal pipes are spoken of as bearing some proportion to their circumference. A "one third mouth," means, therefore, one divisible into the circumference three times. The hiatus of the embouchure, known as the "cut up," from the top of the bottom lip to the edge of the top one, is made proportional to width of mouth; it may be one-fourth of the width, or other proportion according to tone quality desired. These proportions once determined are carried out systematically through the entire compass of a series of pipes forming a stop, to ensure equality of timbre and power, although for reasons concerned both with practical making and timbre, short pipes have slightly larger diameters in proportion to length than long ones.

Wide mouths favour the production of power and ground tone; narrow mouths favour upper harmonic development. One extreme of tone can only be obtained in proportion as the other is sacrificed, but a compromise may be hit upon—as, for instance, a combination of a narrow mouth with a large scale.

The precise effect of the cut-up is conditional on scale and wind pressure

Three lines might be ruled across the upper lip of a pipe of moderate scale: by cutting up to the lowest, tone would be Gamba like; by cutting up to the next above Diapason quality would result; continuing up to the third and highest, a flutiness would become audible; cutting up still farther, the residuum of compound quality would disappear, leaving the prime isolated: all tone would be cut out, to adopt an organ builder's phrase.

In this ideal experiment wind pressure is left out of account, but in practice it would require to be increased by opening the foot in proportion as the mouth was cut up. The result of cutting up under such conditions would be a continual gain in power, as well as the difference in timbre already noticed until the full wind pressure available was reached. Unless this was then increased by adding weight to the

reservoir a decrease in power would continue in proportion as the cut up was made higher, until the pipe would finally cease to speak, the energy of the air stream being absorbed in bridging the gap at the mouth.

The cut up alone, will not, of course, decide tone sufficiently unless associated with correct scale, wind pressure, and other details brought into alignment towards any particular desired result. At the same time the extent to which a pipe is cut up has a most important effect, and nothing is easier than to irretrievably spoil an otherwise correctly made and proportioned pipe by cutting up a shade too high. It may be said, there are three degrees of cut up at which a pipe will produce Gamba, Diapason, or Flute tone in a more or less decided way correlative to scale, wind pressure, and other details of voicing.

The nicking of metal flue pipes is an operation by which minute V-shaped impressions are cut in the languid and bottom lip to steady the tone, and to eliminate a snarling quality generally undesirable. Small spear-pointed instruments of various sizes are used for this purpose, which simultaneously impress the inside edge of the bottom lip, and the bevelled languid after this fashion: —Λ—Λ—Λ—Λ—Λ—Λ—
‾V‾V‾V‾V‾V‾V‾

Diapasons and pipes with few overtones require to be sparsely yet deeply nicked; oppositely, Gambas and small scaled work generally are nicked closely and with faint impression in proportion to the extent it is desired to retain the keenness, in effect on tone, of the untreated edge, so that in many cases the nicking has the appearance of microscopic saw teeth forming a continuous serrated edge

Wood pipes may be nicked on the block alone or on the cap, or both may be so treated. Wood basses are generally nicked on the block alone; 16ft. basses are left, if of large scale, unnicked. The nicking of wood pipes is accomplished by filing linear incisions at an angle to the grain of the wood, thus: ////

The consideration of the effect on tone of material now arises.

What may definitely be stated in this connection is: the larger the scale of a pipe, the thicker should material be.

Weighty, ponderous tone requires like material for pipes to produce it, otherwise, in the somewhat mysterious phrase of the organ builder, they will not "carry the tone." Organ pipes are not required to act in the same way as the body of a violin, to which extends the vibration of strings, thereby bringing under contribution a large surface with which the surrounding air is impressed; but, at least as concerns pipes of "organ tone," elasticity should be replaced by rigidity and material should be of such substance and strength that it will not vibrate easily. It is generally known to organ builders that the tone of pipes intended to produce notes of power and volume, if the metal is thin, may be improved by soldering one or two bands around them.* This points to the presumption that vibration communicated to the body of a pipe from the enclosed air must be subtracted as loss to power; for the gain resulting from the banding of a defective pipe is one of increased firmness and volume of tone.

Further than this. considerations which determine suitability do not rest on tone directly, but indirectly, through the facility with which material may be worked; that is, cut and shaped and made into pipes, and the readiness with which these will receive and retain afterwards impressions made in voicing and tuning; and the absence of such a degree of viscosity in metal pipes that they will not gradually settle down and crumple at foot and mouth. Perversity of material defies craft. Fashions in mechanism change; yet we know a thing of beauty is a joy for as long as it will last, when this concerns the tone of organ pipes. The pipes are the Organ, and worthy specimens will outlast many changes in the fashion of the mechanism whereby music is made.

Extremes of tone are represented by the Open Diapason and the Viole d'Orchestre (a small scaled Gamba). The means conducive to Diapason tone are:

* By merely clasping the hands firmly around the middle of a large scale pipe of thin metal, an improvement in tone will frequently follow until the grip is relaxed again.

Large scale; wide mouth; moderately cut up; deeply and sparsely nicked; copious supply of wind at low pressure.

The specialities of the Gamba are:

Small scale; narrow and low mouth; fine, delicately nicked flue; overblown by wind pressure being, comparatively to scale, high; bearded.

It is written that some people profess to distinguish as far as the sixth harmonic in Diapasons of the "true ring." The Gamba has a much more extended range according to scale and pressure, with a weak ground tone, the concomitant of small scale. Also the ground tone is ushered in by a rapid arpeggio of harmonics elicited in reverse order to the chord incorporated in the tone; these are sharp to the ground tone, and impose on the ear an illusion of quick speech: this peculiarity is due to the beard, assisted by the small scale.

Between the broadly treated Diapason and the delicate Viole, is a gap filled by several stops of intermediate tone. In so far as these stops are treated in the manner of the Diapason will they be bold and pervading; in so far as they are treated like the Gamba will they lose pervading quality and depth, and gain in stringiness and reediness. The following stops indicate this transition from the Open Diapason: Violin Diapason; Salicional; Viola da Gamba; Viole d'Orchestre.

This indicates methods followed with Diapasons and Gambas, further particulars will be found in the list of stops. There are three methods of producing Flute tone, four including the Gedeckt, these are:

(1) The oldest way, by overblowing a pipe with a low mouth, so isolating one harmonic, the first. Overblown wood Flutes were a speciality of early German builders.

(2) Cavaille-Coll's method is now universally adopted in preference to the overblown Flute. It consists in boring one or two small holes at about half the length of an open pipe, and is an easy and sure way of isolating an harmonic.

(3) The method embodied by Bishop in his Clarabella; large scale,

wide mouth, cut up until tone becomes fluty; copious wind supply. Literally a wood Diapason cut up high. Pushing this treatment to an extreme Hope-Jones produced his "Tibia," which yields a powerful prime tone with a very limited range of harmonics. A foundation stop but not a Diapason.

(4) The method employed in the Lieblich Gedeckt, introduced into England by Schulze in 1851, consists in boring a hole through the stopper of the Gedeckt (Stopped Diapason). T. C. Lewis produced beautiful specimens of this stop; his treatment was the provision of a long pierced stopper handle; pipes of thick metal; the top lip was not smoothed down to a bay leaf like the Diapason; and the mouth was cut up semi-circularly to a radius about two-thirds of its width. (Height of mouth, of course, dependent upon wind pressure.)

Further details of voicing, mention of scales, etc., will be found in the list of stops.

REGULATING

After being voiced, a flue pipe may be regulated for power within definite limits of scale and cut up by reducing or enlarging the bore in the foot, so modifying, more or less, the pressure and volume of the wind sounding it. In this way, although a pipe may be standing on a sound-board supplied at a pressure of $3\frac{1}{2}$ins., the actual pressure sounding the pipe might be but half of this figure. In addition to regulating for power, defects of speech come under this heading.

The necessity for regulating comes after pipes have been voiced and they are placed on the wind for the first time. Whenever an organ is dismantled for removal, cleaning, etc., the necessity arises again, as organ pipes are of such delicate constitution that they take umbrage at a touch. In old organs bad regulation is generally accountable to dirt, which first affects reeds and then the small scaled flue pipes.

Few organs leave nothing to be desired in respect of regulation, for the reason that the limit of the time at the disposal of the voicer is oftener reached than the end of his patience or perceptive powers.

With regulating, the ear is the arbiter, the aim being that one pipe shall sound as loud, no more and no less, as every other in a stop; and also what should result from equality of power, equality of timbre; or, if some slight graduation of power from bass to treble is desirable, such should proceed by imperceptible degrees.

"*To louden*" a metal flue pipe (to adopt the convenient phrase) enlarge the bore in the foot by paring away from its circumference by means of a knife or suitable instrument: with small pipes a tapering piece of steel will prove best. The smaller the bore the more delicate the operation. A pipe may be too soft through the flue being accidentally indented, or insufficiently open, or through the boring in the sound-board being too small.

With wood pipes, fitted with the usual turned wooden feet (some have metal feet), regulating for power is a matter of inserting or abstracting plugs of wood.

To soften a metal flue pipe, the bore must be reduced by tapping it closed by means of the flat of a chisel, a hammer, or a special "cupping" tool for the purpose.

When a pipe is "loudened" it sharpens in pitch; therefore a stop of pipes once regulated *and then cut to length* cannot be made louder except within the limit of the overlength left for tuning; to encroach much on this is not only hazardous, but bad craftsmanship. When softening a pipe the limit is not rigid with regard to pitch, but tone quality. When the bore is lessened a piece may be cut off to retain the pitch to standard, but the top lip requires to be lowered if a pipe be softened too far below the power at which it was originally voiced, and this is not possible of accomplishment in a satisfactory way.

THE SPEECH OF FLUE PIPES

Unless specially imitative of some orchestral instrument, flue pipes are intended to speak without being hesitant or inclined to dwell on an overtone.

Some Bourdons sound an harmonic before the fundamental, but this is admittedly a defect, and to avoid it Willis systematically grooved his Bourdons. The same result can be obtained by building up the top of the sound-board and partitioning, so that each pipe stands over a box which absorbs the first shock of the wind. The spaces between the bars of an ordinary slide sound-board serve in capacity of "shock absorbers," and for this reason no one-pipe-one-pallet style of sound-board can approach them for their beneficial effect on the speech of flue pipes. Willis further grooved for flue work in the upperboards.

Unless due to a damaged condition, defects of speech are attributable to slight causes, in consequence remedial by extremely delicate adjustments. Except with metal Gedeckts, and some wood pipes in which the lip is arched more or less, mouths of flue pipes should be linear and angular rather than in any way curvilinear, bulging or indented. The following remarks apply to pipes in which no maladjustment, impediment of "matter in the wrong place," or damage, however slight, is obvious after a critical examination, to the eye. Pipes should be handled in a clean and definite way of craft, without nibbling and worrying, or, on the other hand, using slap-bang methods.

Too quick. A pipe is said to have this defect when it sounds an harmonic before settling to its proper note, or the harmonic may usurp the latter completely. The cause may be that the pipe is too loud. and overblown; or, the top lip may require pressing inwards; or, if the lip cannot be pressed in further without curving, the front of the languid should be raised slightly by means of a thin piece of wood inserted under it at the flue, or by means of a stout wire inserted through the bore, according to the size of the pipe.

Too slow. A pipe is said to be "too slow" when it takes an appreciable though perhaps a short interval to attain its full strength of tone.

As this is the opposite defect to the first, it calls for a reversal of the above treatment; the top lip should be smoothed outwards; or if this adjustment appears correct, the languid should be tapped down slightly.

It should be remembered that large pipes—manual basses and pedal pipes—require more time to "get under way" than small ones.

Windiness. This is often a defect of large scaled basses, and when these stand on the organ screen, the rushing noise becomes objectionable. Splinters of metal at the bore may be the cause, or even sharp edges and roughness in the grooves of the front pipe block. When neither of the foregoing is a cause, treatment usually effective is: close the flue as much as is consistent with correct speech (if closed too much the pipe will become too slow) and compensate by opening the bore until the pipe regains its proper volume of tone. Merely closing the bore will meet the case sometimes of pipes obviously over blown. With Diapasons, the lips may be leathered as a further help. A certain amount of windiness with large basses is unavoidable.

Wavering. unsteadiness of tone. According to Hermann Smith, this defect is due to the periodicity of the air stream at the mouth not being coincident with that of the air column in a pipe, a discrepancy in pitch between the two resulting in beats. It is sometimes the result of overblowing, and may in such case be rectified by closing the bore slightly. Pipes placed in corners of swell boxes or buildings, whereby a sort of false overlength is added to them, are prone to waver. Ears are for the purpose of avoiding this defect. A small wedge of wood* inserted in the flue close to one ear is a good "dodge," resorted to when all else fails; or experimental adjustments of lips and languid may be tried.

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* Known to some as a "Schulze wedge."

With pipes of diapason pattern, metal and wood, the conditions of correct and facile speech are naturally, as it were, complied with. Most other kinds require to be coaxed and persuaded. Diapasons, when slightly overblown by the breath as a test, should rise to their first overtone.

Exigencies of material demand different treatment for the above defects in wood pipes. When a wood pipe is too slow of speech the amending of the defect lies in nicking the block; if that has not been done; or in deepening the nicks if already present, this being the equivalent of pressing the upper lip outwards. Stopped wood pipes readily overblow if supplied with a trifle more wind than their size admits. This reverse defect may be countered by treating the *cap* in the same way, by nicking or increasing the depth of nicks. To lessen the gap at the flue it is necessary to plane down the inner face of the cap; whilst it may be widened by filing. The top edge of the cap is usually kept lower than the top of the block. No sharp or rough edges should be left about the lips and windways of a pipe, such may be smoothed away with fine glass paper. Some continental builders at one time blackleaded and polished the inner surface of the caps of wood pipes to make a smooth surface for the wind to glide over!

As a guide to the treatment of these defects:

(a) Too slow

(b) Too quick.

Any adjustment of a wood or metal flue pipe which tends to direct the sheet of air at the mouth *inwards* counteracts the first *(a)*: whilst any adjustment of block cap, lip, languid, etc., which tends to direct the air *outwards* away from the mouth rectifies the complimentary defect *(b)*.

REED VOICING

It is more exact, perhaps, to speak of the shape of reed resonators, as being of prime importance with regard to tone, rather than scale, as the scale of a single pipe is its diameter, and the scale of a stop refers

to the lessening gradation in diameter between pipe and pipe from the lowest to the highest in pitch. Organ builders speak of reed stops as being of large or small scale similarly with flue pipes, and the application of the term necessarily includes several dimensions in pipes of compound shape.

Most reed pipes are now of the shape of an inverted cone, such as the Trumpet, Horn, Cornopean, Clarion and Tuba; the Clarinet and Vox Humana are cylindrical; the Oboe is of slender tapering shape surmounted by a bell (a truncated inverted cone). Some ancient reeds were of weird and purposeless shapes, such as the Chalumeau and Regal, and by no means standardised extravagancies.

The effect of scale on the tone quality of reeds is the same as has already been noticed in the case of flue pipes, but with a qualification due to the different method of exciting sound vibration. The fundamental tone of the actual vibrating reed is always with us, and even with a small scale fairly assertive. Although the improvement in modern reed tone over ancient examples is largely due to the elimination of the rattling of the tongue against the shallot, this even now certainly gives characteristic quality to reeds as distinct from flue pipes.

Again, compared with a flue pipe, a reed is an economical sound producer in the sense that it utilises wind without waste, for this reason. In a flue pipe the vibration of the air column in the body of the pipe are induced by and secondary to the vibrations of the air stream at the mouth, and a loss of energy takes place. With a reed, air under pressure in the boot is admitted to the resonator as a wave of compression, and is not expended as the motive force in inducing movement in another body of air, but is utilised as half of a sound wave—compression—whilst the rarefaction follows as the reed tongue closes. This fact alone would make reeds more powerful in tone than flue pipes even where scale and wind pressure were equal. It is well known that reeds "use" but a small quantity of wind. In thus taking full advantage of any pressure they may be placed upon, reeds are noted for a rich and varied timbre and extended range of overtones.

With the exception of a few solo reeds of marked characteristic timbre, such as the Oboe and Clarinet, big reeds and chorus reeds are best on high pressure, which is a necessity for harmonic reeds.

For chorus reed work pressures from $5\frac{1}{2}$ins. to 8ins. are not uncommonly used. Hope-Jones frequently employed a pressure of 10ins. even in small buildings. Willis used pressure of 20ins. in several instances for Tubas—as much as 25ins. in one case (St. Paul's Cathedral).

The necessity for high pressure arises in this way. It has been proved that for purity of tone, tongues of thick hard brass are necessary; and the thicker a reed tongue is the more must pressure be increased to vibrate it.

Thin tongues are liable, and when long, certain to give rise to undesirable vibration other than the simple to and fro movement required; tortional and other compound vibrations superimpose, and as these are irregular, they destroy the perfect periodicity necessary for clear musical tone.* Tortional vibrations may be sometimes detected by a continual variation of timbre in the bass of some reed stops, noticeable when single notes are held.

Weighting reed tongues is another auxiliary of the reed voicer. Small brass weights fixed to the ends of reed tongues were originally used by Willis; but the practice now is first to fasten weights upon felt, and cement the felt by means of some reliable adhesive (such as Chatterton's Compound, as used by electricians) to the tongues. This obviates the chance of weights rattling. With light reed tongues felt alone is often sufficient.

After being weighted, a tongue vibrates slower, and must be shortened by knocking the tuning spring down to conform it to pitch. The short tongue being more rigid is not so liable to internal vibration.

The curve of a reed tongue is highly important in effect on tone and power. The technique of reed voicing is simple, but not easy to

* "Noise is produced by an irregular succession of sonorous shocks."—Tyndall.

acquire. Some voicers use an arrangement of rollers through which tongues are passed to impart the curve, but even so it is skill of hand and eye that finally count and must be requisitioned. A steel instrument (burnisher) is pressed upon the tongue which rests upon a hardwood block; this block may be hollowed to a curve and the tongue moulded to it; or it may be simply flat and the curve imparted to the tongue by repeated burnishing.

The reason why a tongue must be curved may be explained in a few words. Obviously, a straight tongue would not vibrate at all, as it would lie close to the shallot, so closing the aperture there; it must therefore, be *(a)* opened away from the shallot at an angle like a partly closed door, or *(b)* curved away. The result of treating a reed tongue in the former way *(a)* may be illustrated by opening the hinged lid of a desk and letting it fall: a forcible impact is the result, not unaccompanied by noise. The result of curving a reed tongue may be illustrated by a rocking chair, which moves on its curved rockers without striking the ground. The difference is one between falling and rolling —between suddenly averted and gradually arrested motion. Curving therefore minimises the sound incidental to the striking of the reed against the shallot For the same reason, shallots are sometimes covered with soft leather, but although it may help in this capacity, the exact shape of the curve is not of less importance even with leathered shallots, as the following paragraph will explain.

Puffs of air are literally the cause of sound in reeds, the tongue serving in capacity of an interruptor of an otherwise continuous stream of air. Professor Robinson first discovered that sound could be produced by puffs of air without the agency of resonators. He used a stop cock attached to a tube which conveyed wind from an organ bellows. By arranging this stop cock to turn on and off "seven hundred and twenty times in a second, the sound *g in alt* was most smoothly uttered." Professor Robinson found that by arranging this "tap" so that its aperture closed except for about one-third, and repeating the experiment, the sound became "uncommonly smooth and sweet."

This illustrates the action of a properly curved reed tongue; the interruption of the stream of air is not complete except for a fractional part of the half of one vibration,* and the admission of puffs of air to the resonator becomes, upon minute analysis, much more gradual and continuous than with a tongue of imperfect and flatter curve.

The curve of a reed tongue should be such that when pressed close against the shallot, with the tip of the finger resting on the wide end, it does not lift, i.e., bulge up, at any part of its length.

The voicing and speech of reeds are inseparable. The amount of curve desirable in any particular case depends upon *(a)* the thickness of the tongue; *(b)* wind pressure; *(c)* volume of tone; and *(d)* quality desired. Reeds of the oboe family are curved less towards the loose extreme of the tongue than those like the trumpet, horn, etc., of freer tone.

The following table illustrates the effect of different degrees of curvature with wind pressure invariable:

Cause	Result.
Insufficiently curved to resist wind pressure	Tongue blows shut against shallot. Silence
Curved just enough to resist wind pressure	Weak sound
Here come a variety of good curves	Correct speech
Excessively curved	Hesitant in speech and too loud
Curved beyond limit of wind pressure to move.	Tongue remains open. Silence.

Further all modern reeds have some form of regulating device at the top of the resonators—similar to the tuning slides or slots of flue pipes—whereby they may be made louder or the reverse.

To louden a reed by means of the regulating device the following procedure is best: first knock up the tuning spring, so lengthening the tongue, until the desired power is reached; secondly tune by means of

* It is even highly probable that a reed tongue never completely closes the aperture in the shallot.

the regulating device--slide, lid or slot as the case may be. The reverse process of first shortening the tongue and then tuning by occlusion makes a reed softer in tone.

A small particle of dust is sufficient to throw a reed off speech. Dust may be detected by holding the reed edgeways against a light, and may be removed by introducing a thin tough piece of paper under the tongue. Where systematic cleaning of reeds is necessary, this method is of course, not suitable: for where reeds have become thoroughly dirty, the shallots should be removed and refaced, and the resonators washed out by water.

A further liability of reeds is that they may be loth to cease vibrating promptly; this may be remedied by piercing the boots of the ones affected.

Pedal reeds are provided, where inertia of tongues has to be overcome, by automatic starters which give the initial fillip requisite to start vibration.

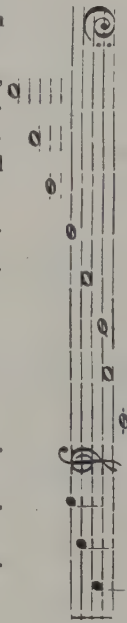
CHAPTER VIII

LIST OF GENERALLY USED STOPS, ETC.

THE following list comprises some particulars concerning most of the well known and generally used organ stops. As stop nomenclature is far from being standardised, we have given names and derivations as found in Mr. J. I. Wedgewood's "Dictionary of Organ Stops." To that well known work we refer readers in search of further knowledge concerning ancient and modern English and continental varieties and usage.

The indications used in this list, as CCCC, CCC, etc., follow the usual system of tablature, as: CCCC, 32ft.; CCC, 16ft.; CC, 8ft.; Tenor C, 4ft.; Middle C, 2ft.; Treble C, 1ft. These "lengths" are merely a convenience, and indicate relative pitch, as organ students are well aware. The following table has been appended as an indication of pitch, relative, and according to one of the standards given, actual, of organ stops ranging from 32ft. to 1ft. The musical notation indicates the limit of the descending scale of stops coming in the 32ft., 16ft.. 8ft.. etc., groups corresponding to CCC of the pedal-board, and CC of the manual keyboard.

SOUNDS OF THE LOW C KEY ON THE ORGAN PRODUCED BY THE LEADING STOPS



Pedal

Double Open Diapason and all 32ft. stops extend an octave lower than the lowest note here indicated

Open Diapason, Stopped Diapason, and all 16ft. stops ... ...

Quint, $10\frac{2}{3}$ft. ... ...

Principal, Flute, Violoncello, and all 8ft. stops ... ...

Twelfth ... ...

Fifteenth ... ...

At Diapason Normal Pitch

Treble C

= 517.84 vibrations

Treble C, Old Philharmonic = 540 vib.

" New Philharmonic or Concert = 522 vib.

" Standard Philosophical = 512 vib.

Manual

Double Diapason, Bourdon and all 16ft. stops

Diapason, Stopped Diapason, and all 8ft. stops

Quint, $5\frac{1}{3}$ft.

Principal, Octave, and all 4ft. stops

Tenth, $3\frac{1}{5}$ft.

Twelfth, $2\frac{2}{3}$ft.

Fifteenth, 2ft.

Seventeenth (or Tierce), $1\frac{3}{5}$ft.

Nineteenth (or Larigst), $1\frac{1}{3}$ft.

Twenty-second, 1ft.

LIST OF GENERALLY USED STOPS

Acoustic Bass, Resultant Bass, Harmonic Bass, Gravitone, Tonitru, 16ft., 32ft., sometimes 64ft. tone.

As a necessary consequence of the combination of two musical sounds, a third sound, distinct from the primaries concerned in its production, is the result. A German organist named Sorge discovered this fact in 1745, and independently, the violinist, Tartini, in 1754. After the Italian violinist they have been called "Tartini's tones." Later Helmholtz established the existence of two kinds of resultant tones, called by him difference tones and summation tones. We are concerned here merely with difference tones.

Difference tones are always present whenever two different notes are combined, but some considerable intensity of the primaries is essential to make the difference tone easily audible.

There is a very simple rule for determining the pitch of these tones: the number of vibrations per second of the resultant note is always equal to the difference between the number of vibrations per second of the notes which are combined.

If, for instance, two notes be combined whose rates of vibration are respectively 32 and 48, then $48 - 32$ = the difference tone, 16 vibrations per second.

The theory of resultant tones, which were once ascribed to the coalescence of rapid beats, is not easy to condense into a few lines, and it is not our purpose to undertake explanations of what belongs purely to the scientific side of the subject: further, we have in mind that the reader has forestalled us, and that the following table of resultant notes from the combination of a few of the harmonic intervals will be sufficient for our purpose.

Interval	Ratio of Vibration	Difference	The resultant tone is deeper than the lowest primary by:
Octave	1 : 2	1	0
Fifth*	2 : 3	1	An octave
Fourth	3 : 4	1	A twelfth
Major third	4 : 5	1	Two octaves

The interval of a fifth, marked with an asterisk, is the one selected in organs to produce something of the effect of 16ft. or 32ft. stops. According to the above table and the rule already quoted, the combination of a note of 16ft. pitch with a Quint of $10\frac{2}{3}$ft. pitch, a difference tone of 32ft. pitch will result.

This may be accomplished by a compound stop of two ranks, or by adding seven pipes to the usual thirty of the pedal compass, and coupling pneumatically or electrically in fifths. For several reasons, the former method is best, but of course the most expensive. For the reason that the difference tone is necessarily much weaker than the

primaries and as the fundamental law of its strength lies in the strength of these, it is always a submerged tone, and as such inferior to a primary note obtained directly from a single pipe.

Bass Flute—Pedal Flute, 8ft.

The so-called "Bass" Flute is usually of stopped pipes, frequently merely borrowed from the Bourdon, the treble octave alone bringing additional pipes. If a separate stop to the Bourdon and of stopped pipes, it is voiced similarly to a Lieblich Gedeckt, but is generally of wood. Open pipes are, of course, preferable for this stop.

Bassoon—Fagotto. (Fr.) Bassoon; (Ger.) Faggott. 8ft., 16ft.

The Oboe and the Clarinet have sometimes what is known as a Bassoon bass: this means that the twelve lowest notes have full length metal bodies of inverted conical shape, of very small scale—literally the Oboe shape without the bell. The bassoon of the orchestra is a wood-wind instrument with a double reed mouthpiece, forming the bass of the oboe family. Except as a bass, the Bassoon is not used by English organ-builders at 8ft. pitch. The Contra Fagotto (16ft.) is now a small scaled metal stop, though at one time it was usually made with wood bodies fitted into metal boots: it is voiced of a more "free" tone than the Bassoon bass. The Contra Fagotto is used in the Swell, and also as a soft Pedal reed. As a Bassoon bass the scale is about $2\frac{1}{4}$ ins. at CC; as a Contra Fagotto about 5ins. at CCC.

Bell Gamba—Glocken-Gamba (Ger.); Glocke, bell. 8ft., rarely 16ft.

A large scaled Gamba surmounted with a bell; this was sometimes made separately from the cylindrical pipe, and placed in the top like a tun-dish, so that the pipe could be accurately cut to length, and tuned by sliding the bell up or down. This represents an improvement in the earliest form, which was tuned by means of "shading" ears at the mouth. "Bell" flue stops are now obsolete, together with the kind of tone produced from them, which had both body and pungency.

Bombarde—Bombardon. Pedal, 32ft., 16ft.; Manual, 16ft.; rarely 8ft.

A name given to what may be described as a smooth reed of powerful tone.

Bourdon—(Ger.) Bordun; (Fr.) Bourdon

In England the Bourdon is a manual or pedal stop of 16ft. pitch. On the Continent it is of 16ft. or 8ft. pitch as a manual stop; and 8ft. pitch on the pedal.

The Bourdon is of completely stopped wood pipes rectangular in section; as is usually the case also with the Pedal Open Diapason, the four sides of a pipe are generally of equal width, consequently when these are nailed and glued together they form, not a square, but a departure from that shape, according to the thickness of wood used. The old manner of voicing was to cut up but little, the first harmonic (twelfth) by this means became predominant, unpleasantly so to modern ears; a sort of buzzing "bee in a bottle" tone was the result, hence, possibly, the name. Bourdons are now well cut up to a slight curve, after the fashion of Gedeckts. A soft Bourdon is sometimes included in the Swell, and borrowed pneumatically or electrically for the Pedal (Echo Bourdon). Unless all the tone is cut out of Bourdon pipes, or what amounts to the same thing, they are kept unduly soft, they are invariably "too quick" in speech, the defect not being amenable to ordinary treatment. (See Regulating.) As previously mentioned, provision should be made to counteract this in the sound-board.

The scales of Bourdons vary greatly, as with stopped pipes timbre is chiefly modifiable by treatment in voicing as regards distinctive qualities other than depth and pervasiveness, which are attributes of large scale pipes.

A large scale is 12ins. across the mouth of the CCC pipe: the smallest scale is 4ins.

CARILLON—Clochettes; Gongs; Glockenspiel; Stahlspiel.

According to Mr. J I. Wedgwood, the Carillon stop is either: (1) real bells; (2) gongs; (3) tubular bells, i.e., hollow steel rods; (4) an acute Mixture of three or four ranks.

Some form of pneumatic or electro-pneumatic percussion action is arranged to strike bells and gongs, in this way playable from one of the manuals. Drums are another form of percussion instrument sometimes used in organs, playable from a pedal note.

CHALUMEAU—(Ger.) Schalmei, Shalomo, Schalmay; (Fr.) Chalemie; (Lat.) Calamus, a blade or stalk. 16ft., 8ft.

The Chalumeau was the Alpine shepherd's pipe, of "pastoral reed" sound. The first known reed-organ stop was of that name. The stop is, and was, subject to variable treatment. A Double Oboe is sometimes called Chalumeau.

CLARABELLA—Claribel Flute. (Lat.) clarus, bright, and bellus, beautiful. 8ft., 4ft.; rarely 16ft.

The Clarabella of the Bishop type is of large scale, copiously winded and cut up high, the pipes being of wood, tuned by a metal lid; the lip is thick and glass-papered to a rounded edge. The tone has considerable body of unimitative flute quality, and is equally useful for combinative and solo purposes. It is a wood Diapason, voiced fluty. The Tibia Plena (sometimes called Tibia Major or Major Flute) of Hope-Jones is an exaggeration of this treatment, designed to supply the maximum of foundation tone without loss of all blending properties. Willis made Harmonic Claribel Flutes of metal—a variety of harmonic Diapasons.

The Waldflöte is on similar lines to the Clarabella, but of smaller scale with an inverted mouth and slotted top, tuned by a covering piece: its tone acquires a mild tinge of Gamba quality.

The Hohl Flute is a small scaled Clarabella, sometimes made

with an inverted mouth, which is cut in the pipe some distance above the level of the block ("sunk block").

T. C. Lewis constructed Hohl Flutes with the mouths on the widest sides of the pipes, a departure from his rule in respect of other wood stops.

Wood stops of this class have half stopped basses; the open pipes generally begin at Middle C. Scale of Middle C, $1\frac{3}{4}$ by $2\frac{1}{4}$.

Clarinet—(Ger.) Klarinette; (Ger. and Fr.) Clarinette; also Corno di Bassetto; Orchestral Clarinet; Cremona; (Fr.) Carmorne, Cromorne; and (Ger.) Krummhorn; (It.) Clarinetto; (Lat.) Clarus, clear. 8ft., 16ft.

The clarinet of the orchestra is of wood with a curved mouthpiece, to which is bound a thin slip of Spanish reed; the curve being imparted to the mouthpiece, the reed is straight, oppositely to the condition existing in the Clarinet of the organ. The orchestral clarinet is said to have been derived from the primitive chalumeau. The Tenor Clarinet of the orchestra is known as the Basset-Horn.

The Clarinet is peculiar amongst orchestral reed instruments in requiring the highest pressure to produce its lowest notes. (From 15in. to 8in. lowest to highest note.)

The Clarinet of the organ is of short length pipes, cylindrical, now completely capped, with a wide slot at the top partly covered with a clip (as used for tuning some flue pipes) for the purpose of regulation. The organ stop has a peculiarity of scale related to the one of pressure noticed in the orchestral instrument, inasmuch that the scale of the bass is out of proportion in being comparatively smaller to that of the treble in a marked degree. Scales range from $1\frac{3}{4}$in. to $1\frac{1}{4}$in. at CC to diameters of $\frac{3}{4}$in to 1in. for the top note; the graduation in the bass octave being minute. This is the organ builders' way of attempting by scale what is obtained in the orchestral instrument by pressure. The Clarinet is the most delicate of the orthodox organ reeds to voice, and does not stand well in tune, owing to the fact that the short length bodies

exercise no such help to the tongues as is afforded when the periodicity of the two coincide.

The tongues in the bass should be weighted to avoid rattling and coarseness of tone.

Some Clarinets have a Bassoon bass, for which see Bassoon, Double Clarinets are not unknown. Clarinets are not amenable to organ treatment in the same way, for instance, as the Oboe, and are therefore purely for solo purposes.

Clarion—Clairon, Clarin, Clarino. (It.) Clarino, a small Trumpet, 4ft.

A clarion was a shrill-sounding trumpet formerly employed as a call to arms. The stop is an octave reed for combinational use usually with the Trumpet or Cornopean: it is most satisfactory of double length, i.e., harmonic.

Contra Bass—Kontra Bass, 16ft.

The prefix contra applied to organ stops is synonymous with double; these words indicate sub-octave to unison pitch.

The Contra Bass is a pedal Gamba of large scale imitative of the orchestral double bass.

Cor Anglais—Corno Inglese, English Horn, 16ft., 8ft.

The Cor Anglais of the orchestra belongs to the oboe family, but has a larger bell and tube than the oboe.

The organ stop is imitative, like the Oboe in shape but surmounted with a double bell—two truncated metal cones soldered together at their bases. The tone is penetrating and wailing. It was much used in French organs as a free reed stop, and many specimens were imported into this country. It has been made by English builders as a beating reed.

Cornopean—8ft.

A smooth reed suitable for the Swell, invented by William Hill. When on a fairly heavy pressure and harmonic (from Middle C, preferably) it acquires something of the Tuba clarity of tone.

Diapason—(Fr.) Montre; (Ger.) Principal. 32ft., 16ft., 8ft., 4ft., 2ft.; and Mutation

With reference to this name, Dr. J. W. Hinton writes:* " . . . . a word seemingly used without any clear or defined meaning, although its Greek original . . . . 'through all' is plain enough if it could only in some way be connected with what we call the Diapasons in an organ."

Mr. J. I. Wedgewood gives the derivation from an abbreviation of a Greek phrase meaning, according to the "Century Dictionary," "a concord through all the tones," further amplified as "a concord of the two tones obtained by passing through all the tones."

"A concord through all the tones" might be applied to the consonance of the Diapason partials combined within the timbre.

In England and America Diapasons are open pipes of large scale forming the principal organ groundwork. The 8ft. stop is the standard, and the term includes sub-octave, octave, super octave work, etc.: the tone is peculiar to the organ.

The French appropriate the term to signify "pitch"—Diapason Normal pitch is C = 517.84 vibrations per second at 60° Far.

Diapason—8ft.

The pipes in this stop are preferably made of metal throughout the compass, as was commonly the case in old organs when this material

* "Organ Construction" J. W Hinton.

was cheap: they are the largest in scale of all flue work, cylindrical in shape, and open, i.e., unstopped.

Most builders are now compelled to economise by using zinc basses, but sometimes in the Swell, the preference is given to wood. A skilful voicer can make a bass of open wood pipes tonally indistinguishable from a metal one, but, it may be added, the pipes must be specially designed to this end.

The weight of a Diapason of good scale suitable for the Great, would not be excessive at 4 cwt. Of this quantity the three largest pipes, CC, CC sharp and DD, would appropriate nearly 168lbs.: from Tenor C to the top note the weight might reasonably be about 150 lbs.

A "special" metal often used now for Diapasons, contains no alloy but antimony to harden. Antimony makes for brittleness as well as hardness, and from the point of view of the voicer and tuner, is not a good alloy. Considerations of monetary cost also bulk largely in this matter, and generally decide the issue. Unfortunately, in these days, tin and lead are not made precious by art alone.

The late Mr. T. C. Lewis, famous for his Diapasons, has published the following particulars as his standard of an ideal Diapason*: Middle C, $2\frac{3}{16}$in. diameter; mouth, $\frac{1}{4}$ circumference cut up $\frac{15}{32}$ in.; bore, $\frac{7}{16}$in.; wind pressure, $3\frac{1}{2}$in.; pitch, $267\frac{1}{2}$ vibrations at 60° Fahr.

This is a big scale compared to the usual Diapason, 6in. Double C; Tenor C, $3\frac{3}{8}$; Middle C, 2in.

In order to avoid "sympathy" and to differentiate in power and tone, it is usual with two or more Diapasons standing on the same sound-board to make them of different scales, and for the one reason of variety, to afford different treatment in scale or voicing to those, for instance, in the Swell as contrasted to those on the Great.

Comparatively low pressures have been found best for Diapasons —from $3\frac{1}{2}$ to 4ins. High pressures result in windiness, and, more

* In "A Protest against the Modern Development of Unmusical Tone," by the late Thomas C. Lewis, page 5.

over, if employed, must be reduced by closing up the foot; which appears *prima facie*, an argument against their usefulness.

The mouths of Diapasons are generally one-fourth of their circumference, cut up one-third of the width of the mouth. Diapasons have been made with wider mouths, but such are likely to encourage defects of speech. The pipes may be cut up slightly more or less than one-third, according to wind pressure, power, and tone quality. Cutting up beyond a limit defined by the wind pressure produces undesirable flutiness; whilst the other extreme, low mouth, tends towards undue predominance of "Gamba" partials—brilliance.

In order to produce more fundamental quality—and smooth, round tone—the upper lip may be leathered; this means a strip of leather exactly the width of the mouth is fixed by some reliable adhesive so that it covers the outside and inside surface of the lip, thereby producing a smooth, rounded, thick edge. This was, originally, the treatment of Hope-Jones's "Diapason Phonon." With Diapason work, the aim is to avoid a keen knife-edge to the lip, and, what is equally important, it should be thick—hence the utility of leathering Diapasons. Some builders now increase the thickness of the lip by reinforcing the metal of that part, which is perhaps preferable to leathering.

Diaphone—32ft., 16ft., 8ft.

A Hope-Jones specialty referred to previously in this book. Its usefulness is limited to the Pedal department. See page 121.

Dolce—(It.) Dolce, sweet. 8ft., 4ft.

The shape is an inversion of the Gemshorn pattern—wider at the top than at the mouth; the tone soft and distinctive. These pipes are only with difficulty made to "speak" correctly.

Double Diapason—Manual, 16ft.; Pedal, 32ft.

The manual Double Diapason is of metal, of smaller scale than the 8ft. stop, the bass and tenor octaves usually of zinc. The Swell "Double," owing to limitations of space, is frequently of stopped wood pipes—literally a small Bourdon. Scale of CCC 9in. or 10in. (Open, metal).

The Pedal Double Diapason (32ft.) called also Open Diapason or Major Bass, is variably of wood or zinc. Willis experimented with iron pipes in the organ at St. George's Hall, Liverpool, but the result was not satisfactory. At the Albert Hall is a 32ft. stop by Willis of metal (of 90 per cent. tin), the four lowest notes of which are said to have cost £800.

Scales vary much; about 22in. across the mouth of the longest pipe when of wood, and 16in. diameter when of metal, are ordinary scales.

Dulciana—(Lat.) Dulcis, sweet. 8ft., 16ft.

The Dulciana was originally voiced as an extremtly soft Diapason. The method adopted—and in essentials still followed—was small scale and extremely small bore, which necessitated a low mouth. It is now voiced more after the Gamba fashion, with finer nicking and chamfered lip. The pipes are of metal, and cylindrical. The bass often shares the honour of the position on the organ screen with the Great Diapason basses.

Scale of CC usually 3½in. to 4in. to as much as 4½in.

The prefix "Echo" before Dulciana has its usual significance when applied to organ stops, which is, exceptional softness.

Fifteenth, 2ft.

Octave to Principal 4ft., voiced as a continuation in tone of that stop. The pitch of this is sufficient for its purpose of imparting brilliance to the Diapasons without making it "shriek." A Super Octave is an octave to the 4ft. stop of that name (Octave) voiced similarly.

Although the aim is to produce Diapason tone, each ascending step in pitch with these stops, octave, super-octave, etc., to the 8ft. standard is accompanied by a slight decrease in scale. Similarly, Diapasons lower in pitch to the 8ft. standard are comparatively smaller in scale.

Flageolet, 2ft.

Similar to the Fifteenth, but of more fluty tone. The old Flageolet was usually an octave Gemshorn, similarly tapering in shape, but cut up higher. Except for the top octave, this stop is sometimes of wood.

The orchestral instrument is of "whistle" construction, after the fashion of a flue pipe.

Flauto Traverso—Flute Allemande, Flute Traversiere, Vienna Flute, and numerous other names. (Lat.) Transversus, or Traversus, across. 4ft., 8ft.

This stop is imitative, and the cap and mouth were arranged so that the pipe was blown after the fashion of the orchestral instrument. Now the name is applied to a small scaled Flute of the Cavaille-Coll harmonic pattern, of metal, which, like most harmonic stops, is continued below Middle C with pipes of normal length.

Flute—32ft., 16ft., 8ft., 4ft., 2ft., 1ft.; and Mutation

A name for a class of stops, generally of wood, allied structurally or tonally of less complex quality than Diapasons. (See page 138.)

Gamba—Viola da Gamba, Viola, String Gamba, 8ft., 16ft.; occasionally 4ft.

Gamba is used as a generic name for a class of stops imitative of the violin family of the orchestra; but the range of pitch is more restricted in the ascending scale, both from natural and practical reasons

concerned with the preservation of the quality, than with Diapasons and Flutes.

Stops of various degrees of quality and power are labelled with the above names. Most Gambas are now bearded, which gives a certain sameness of timbre, irrespective of degrees of keenness. Gambas of Dulciana scale can be voiced without beards, and although the task is troublesome it yields a result distinct from the ordinary bearded Gamba.

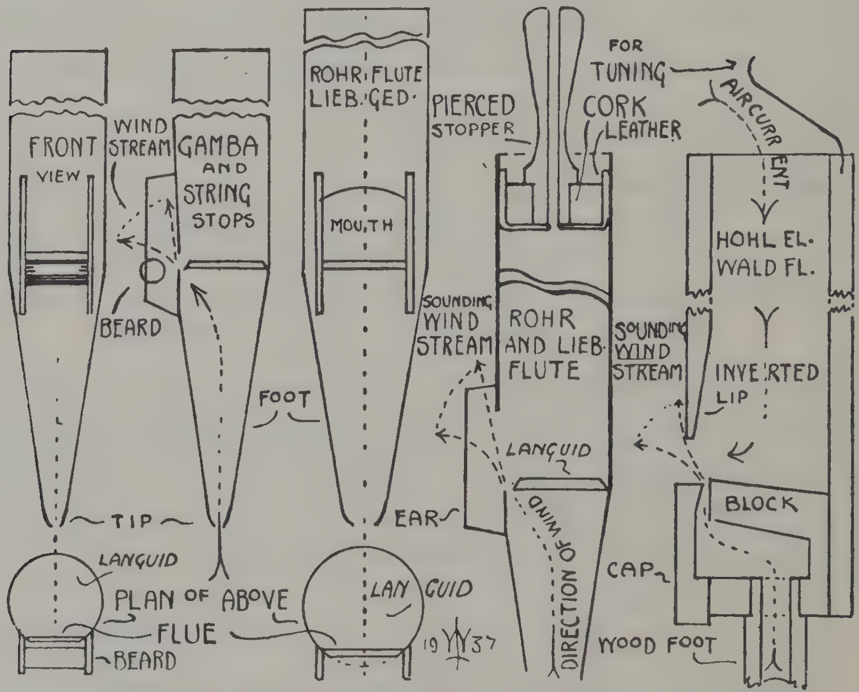


Plate 45

DETAILS OF FLUE PIPES. LEFT TO RIGHT, METAL STRING-TUNED, METAL STOPPED FLUTES, WOOD OPEN FLUTES. (HOHL, WALD)

The small scale and low mouth of the Gamba have already been noted, it remains to mention the importance of the "beard" to the modern type of this stop.

Schulze is generally credited with introducing the "bar" beard into England (a flat piece of metal or wood placed in front of the

mouth), and T. C. Lewis the "roller" form. Numerous other varieties of beards have been used, but the roller form now finds most favour. (See Plate 45.) This consists of a piece of wood circular or oval in cross-section, held in position between the ears of pipes by means of pins. Gambas are first overblown to the octave (first harmonic), and the beard so adjusted that the fundamental is resumed. The smaller the scale of a pipe the larger must be the diameter of the beard. This device makes possible a range of tone from a faint reedy suggestion to an intense assertive keenness, and is a necessity with extremely small scaled pipes to combat defects of speech otherwise unavoidable.

Owing to their small scale and desirable thinness of material, these stops are undoubtedly best of almost pure tin. Gambas are generally slotted to enhance their stringiness, and as a convenience for tuning.

Zinc is frequently used as a material for basses, and, but rarely, wood.

Scales: CC, $4\frac{1}{2}$ to 3ins.

GEDECKT—Stopped Diapason (which see), (Old Ger.) Gedacht, (Ger.) Gedecht, covered, 8ft., 16ft., 4ft.

The modern Gedecht is of stopped metal pipes, with arched lips which are not smoothed down from the round contour of the bodies to the customary bay leaf formation*: the stoppers are pierced. Scales vary considerably according to power desired. The tone is sweet, fluty and hollow, the speech exceedingly prompt.

GEIGEN PRINCIPAL—Violin Diapason, 8ft., 4ft.

A stringy Diapason, smaller in scale than foundation Diapasons, with lower mouth and finer nicking. The basses are generally bearded and the pipes slotted. It is sometimes used at 4ft. pitch in lieu of an

* This term, bay leaf, as a matter of fact, is only applied in cases where the top lip draws upwards to a point, like a larcet window, a method followed with front pipes for decorative effect.

ordinary Principal in the Swell. Scale, CC, 5in. An octave Geigen would be about two pipes smaller in scale than the 8ft. stop.

GEMSHORN—(Ger.) Gemse, goat. 4ft.

The pipes are conical in shape, diminishing at the top of a pipe to one-third of the diameter at the mouth. The tone is delicate and with a tinge of string quality. It is valuable as a Swell octave stop. The name is sometimes given to a stop composed of ordinary cylindrical pipes when in the Swell, and less frequently on the same manual a true Gemshorn may be labelled Principal.

HARMONIC FLUTE—(Fr.) Flute Harmonique; (Ger.) Harmonieflöte. 8ft., 4ft.

The invention of the French organ builder, Cavaille-Coll (see page 138). The stop is harmonic usually to Middle or Tenor C. the bass being of pipes of normal length of large scale.

HARMONIC PIPES

Pipes so treated that they sound their first harmonic instead of the prime.

The first harmonic of an open pipe is an octave higher than the prime; the first of a stopped pipe is a twelfth to the prime. The vibratory rates are thus twice and three times respectively those of the primes.

The Harmonic Flute, 4ft., has therefore a *speaking* length twice that of the Principal, 4ft.; and the Zauber Flute, 8ft., a *speaking* length three times that of the Stopped Diapason, 8ft.

This is impossible to express exactly in terms of stop nomenclature, and to resort to the "scientific" relation of length to pitch fosters an inexactitude as great as that in the organ between indicated lengths on draw knobs and actual speaking lengths. (See Harmonic Flute, Tuba, Zauber Flute, and pages 138, 125 to 129.)

The difference between harmonic flue and harmonic reed pipes is, in the former the harmonic is isolated, whilst in the latter the fundamental note of the vibrating reed has a vibratory rate one-half that of the "double length" tube; thus the fundamental note of the reed is unisonant with the first harmonic of the tube. The tubes of harmonic reeds are not pierced.

Hohlflote—Hohlflute, Hohl Flute, 8ft.

This stop may be described as a kind of small scaled Clarabella, which see. It is generally of wood with inverted mouth and sunk block.

Horn, 8ft.

A stop originally imitative of the French hunting horn, now treated as between the Cornopean, of smooth tone, and the trumpet of free clangy tone.

Horn Diapason, 8ft.

A stop slightly smaller in scale than the Diapason and larger than the Violin Diapason, of more power than the latter.

Keraulophon, 8ft.

Now seldom, if ever, included in new specifications. Of medium scale, with a piece of "over" or "false" length, i.e., the extra length left for tuning purposes in the ordinary way is increased and rendered partially ineffective by a slot or hole.

Lieblich Gedecht—Lieblich Gedacht. (Ger.) Lieblich, lovely. 8ft., 4ft.

The Lieblich Gedecht is a small scaled Gedeckt, the tone being consequently brighter than the latter. The Rohrflöte belongs to this family, and the Lieblich Flöte, 4ft. The ordinary Bourdon may be

classed with these,* and also the smaller scaled Lieblich Bourdon, both of course, 16ft. Stops of this class are seldom made at 2ft pitch, and when they are it is impractical to continue with stopped pipes right up to the top note. The old chimney flute is the predecessor, tonally and structurally, of the Gedeckt family, the pierced stopper handle now being a more perfect mechanical means for tuning than the sliding telescopic cap with its attached metal tube. The basses of Gedeckts are completely stopped, as piercing is without tonal effect with pipes of low pitch: it is unusual to pierce below Tenor C with an 8ft. stop.

Mixtures—(Lat.) Miscere, to mix.

Mixtures are a species of compound stop, i.e., stops in which two or more series of pipes are under the control of one draw knob. The technical equivalent for series as here used is ranks. Mixtures include one or more Mutation ranks, i.e., pipes speaking a note other than that of the key struck, or other than an octave, double octave, etc., equivalent. Thus the Quint, sounding G on the C key, and the Twelfth, an octave Quint, are Mutation stops. The Mutation ranks are tuned perfect (without beats) to the pitch.

As compared with the orchestra, the organ was deficient in notes of extremely high pitch incorporate in the tone as harmonics. The Mixture was introduced before the development of modern string and reed tone reduced this deficit, to, perhaps, inconsequential proportions, as a means of artificially filling the lacuna. Students are well aware of the misdirection given to organ building by the cult of the Mixture, and the culmination thereof in the organ built by Gabler (1750) for the Monastic Church at Weingarten, an instrument pleasantly compounded of ninety-five ranks of Mixture. Almost every possible cacophony has been tried with Mixtures, but it is now apparently considered desirable to make them of few (comparatively) and harmonious ranks. Even

* More exactly, with the old Stopped Diapason, because only a few top notes of the Bourdon have pierced stoppers.

so however, this stop is too often exemplified as a mere conventional survival, best left unused.

Mixtures are usually made with Diapason pipes, although string toned Mixtures have been successfully employed. Mutation ranks in these stops have also been constructed of double length and made harmonic; by this means they stand better in tune, and owing to the simplicity of their timbre, introduce the minimum of harmonics from within their own composite tone.

There are many old kinds of this stop, but the old names have ceased to retain their significance. Now it would appear, *a posteriori*, there are two general methods of procedure: (1) to make the stop a thing beautiful intrinsically, as with the Dulciana Mixture, and string toned Mixture; (2) to postpone this effect to the result, so that the stop might be of value in combinational use merely as imparting brilliance or some other timbre creating value.

As an example of a Diapason Mixture beautiful in itself, designed to extend the tone of the Great Organ Diapasons, is one at St. Andrew's Hall, Glasgow (T. C. Lewis). It comprises the following ranks:

Diapason,	8 ft.	Fifteenth,	2 ft.
Principal,	4 ft.	Nineteenth,	$1\frac{1}{3}$ft. (One break)
Twelfth,	$2\frac{2}{3}$ft.	Twenty-second,	1 ft. (One break).

This follows the harmonic series with two omissions; the Seventeenth or Tierce (number 5 of the series); and the Flat Twenty-first (number 7 of the series).

The technical meaning of "break" is a reversion to a lower pitch, as with ranks above the compass of the Fifteenth it becomes impractical to continue unbroken semi-tonal progression from bass to treble, thus:

Breaks	Intervals of ranks (Diapason = 1)
1. CC to F, 19 notes	15, 19, 22
2. Fid. G to C, 18 notes	15, 8, 12
3. C to top note	15, 8, 1

"In the trade," this would be written in terms of stop nomenclature, as (in order of longest speaking length first):

1st Break: Fifteenth; Nineteenth; Twenty-second.
2nd Break: Principal; Twelfth; Fifteenth.
3rd Break: Open Diapason; Principal; Fifteenth.

OBOE—(Fr.) Hautbois; (Ger.) Hoboe. 8ft., 16ft.

A well-known reed of inverted conical shape, surmounted by a bell and lidded. The ordinary Oboe is designed for solo and combinational use. The Orchestral Oboe so-called is of much smaller scale, sometimes unprovided with a bell and of short length, and intended primarily for solo use. The Oboe is sometimes provided with a Bassoon bass, a fact that may or may not be indicated on the draw knob. (See Bassoon.)

OPEN DIAPASON (pedal), 16ft. For the 8ft. stop, see Diapason.

The Pedal Open Diapason so-called is of wood, generally of large scale and ponderous tone. The pipes are "bellied," i.e., larger at the middle than at the top and block. This is the usual manner of constructing all wood pipes, but in the case of this and the wood 32ft. stop the treatment is exaggerated on account of the large size of the pipes. This practice is said to give better tonal results than if the pipes were made simply of straight pieces of wood, but the explanatior probably is that it is a matter of great difficulty to plane a long joint unerringly true, i.e., it will be either slightly concave or convex. The first is fatal, so the joint is planed convex. This shape also, for mechanical reasons, is more conducive to a perfectly sound joint, an essential condition for speaking pipes. Scale: 12ins. by 10ins. is ordinary for CCC.

PICCOLO, 2ft.

A metal stop, preferably harmonic.

POSAUNE—(Ger.) Trumpet. Man. 8ft., Pedal, 16ft.

A soft reed of the Trumpet kind, which see.

PRINCIPAL—(Ger.) Prinzipal, 4ft.

A name given in Germany to the principal stop in the Organ, the Diapason. In this country an octave Diapason of smaller scale than that stop. The name Octave distinguishes a stop scaled to the Diapason, of louder and broader tone than the Principal.

QUINT—(Lat.) Quintus, fifth; Man., $5\frac{1}{3}$ft.; Ped., $10\frac{2}{3}$ft.

A Mutation stop speaking a fifth to the Diapason when on a manual, and a sub-octave fifth when on the Pedal. Its value is a timbre creating one as a manual stop, and it may form one rank of the Acoustic Bass on the Pedal, which see.

ROHRFLOTE—Rohr Gedeckt. (Fr.) Flute-a-Cheminee; Chimney Flute; 8ft., 4ft., 16ft.

The old Flute-a-Cheminee was of metal pipes, stopped by means of a metal cap through which was perforated a hole surmounted by a metal tube. The pipes were tuned by means of the ears, which were made long enough to shade the mouth. The length and diameter of the tube or chimney affected timbre. The modern Rohrflote is a large Lieblich Gedecht, which see.

SALICIONAL, 8ft., 16ft.; also SALICET, 4ft.

In this country the Salicional is midway in tone between the Dulciana and String Gamba. The pipes are cylindrical and usually slotted, the basses sometimes bearded. The Salicet is an octave Salicional.

SLOTTED PIPES

When flue pipes are slotted they are made longer than is necessary to tune them with cups or cones, the overlength being perforated by a perpendicular cut which begins close to the top, and is partially cov-

ered with a movable clip for tuning. This adds more colour to the tone: probably tends to introduce or intensify discordant partials. Gambas are usually slotted, and so also are some open wood pipes.

Most reeds are now slotted for regulating.

STOPPED DIAPASON, 8ft., 16ft.; sometimes 4ft.

The old type of this stop has ceased to be; it is now voiced as a Lieblich Gedeckt. Formerly it was of completely stopped wood pipes rectangular in cross-section, as near as could be in that material, of Diapason pattern.

TIBIA—(Late Lat.) Tibia, a pipe, meaning originally shin-bone.

The Tibia is said to have been a flute with several finger holes. The name has been applied to Flute stops on the Continent for centuries. Hope-Jones applied the name to a large scaled powerful Clarabella, which see. Tibia Plena, 8ft.; Tibia Profunda, 16ft.; and Tibia Profundissima, 32ft., is the Hope-Jones nomenclature for his scientific foundation stops.

TROMBA, 8ft., 16ft.

A powerful reed of the Trumpet kind.

TROMBONE, 16ft., 32ft.

A double reed similar to the Tromba. The equivalent Posaune (Ger.) is usually applied to a stop of softer character.

TRUMPET, 8ft.

A large scaled reed of inverted conical shape, uncapped: the tongues of reeds of the Trumpet kind are curved more acutely towards their free ends than those of the Oboe kind. The tone is generally rather coarse as well as powerful unless the stop is on a fairly heavy pressure and harmonic; under such circumstances it acquires the Tuba quality. The true Trumpet tone is a rarity.

Tuba, 8ft.

The Tuba is a large scaled reed, planted on a heavy pressure, the upper portion of the compass being harmonic, preferably to Middle C. A pressure of 20ins. for this reed is not considered excessive in a large organ.* As used in organs of various sizes by different builders, pressures range from about 8ins. to as much as 25ins. in an exceptional instance. The tone is smooth, clear and powerful, and the speech prompt. The stop is not unknown at 16ft. and 4ft. pitch. (Double Tuba, Clarion Tuba; Willis.) The affix Minor refers to a Tuba of less power than ordinary.

Twelfth, $2\frac{2}{3}$ft.

The ordinary Twelfth is of Diapason pipes, and forms an interval of a twelfth to the Diapason to amplify the natural harmonic of like interval.

Viole d'Orchestre—Viola d'Orchestra, 8ft.; also Octave Viol, 4ft.

The Viole d'Orchestre is a Gamba of extremely small scale. Hope-Jones introduced a scale of $1\frac{1}{16}$in. at CC Pipes as small as this are so delicate that their speech is soon affected by dust particles. For this reason such a scale cannot be considered practical; $2\frac{1}{4}$in. at CC is small enough, unless a high wind pressure is used, which will allow of a still smaller diameter.

Violin Diapason

A stop between a Diapason and a Gamba. (See Geigen Principal.)

Violone—Violon, 16ft.

The Violon is usually found on the Pedal, and may be of wood or metal. It is treated as a Gamba, with low mouth, bearded and

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* And in large buildings. It is impossible to employ heavy pressures for pipe work in small buildings and obtain a satisfactory result.

slotted, and, if of wood, with a retreating block and chamfered cap; and is tonally imitative of the orchestral double bass.

VOIX CELESTE—Vox Angelica, Vox Cælestes; also Viole Celeste, 8ft.

The Voix Celeste, usually of Tenor C compass, is tuned either slightly flat or sharp to another stop of similar tone, so that by the combinative use of the two an undulating effect is produced due to beats. Formerly it was the practice to groove the Celeste from its companion stop, so that it was a compound stop of two "unisonant" (or practically unisonant) ranks on one slide. Now, by having the Celeste on its own separate slide, the companion stop, usually Salicional, is made available for selective usage, and the two may be coupled by mechanical or pneumatic means to the Celeste draw knob, still leaving the other free.

A Dulciana Celeste, composed of two Dulcianas, is sometimes called Vox Angelica, but this name is by no means confined to one particular variety of tone, although a Vox Angelica is generally admitted to be of milder tone than a Celeste. It is usual to employ stops of slightly disparite stringiness, but the difference must not be too great; for instance, a Dulciana will not "beat" with a String Gamba in a satisfactory way.

The double Celeste (introduced by T. Casson) is an ingenious means of apparently lessening the dissonance of the old type of stop. Two beating ranks are used, slightly sharp and flat respectively to a middle rank.

VOX HUMANA—(Fr.) Voix Humaine, 8ft.

The Vox Humana in this country is a reed of the Clarinet kind; the actual lengths for CC are various and arbitrary; that note may have a pipe as short as 12ins. The pipes are cylindrical, with a cap and slide. The tone, popularly known as being imitative of the human voice, is thin and hollow, owing to the fact that the fundamental note of the reed is separated by a wide interval from the high partials pro-

duced by the short resonator. To enhance the effect of this stop, it is invariably enclosed, sometimes separately from the Swell, and is used with the Tremulant.

Waldflote—Feldflote. (Ger.) Feld, field. 8ft., 4ft.

An open wood Flute of the Clarabella kind, which see: it is constructed with an inverted mouth, sometimes with a sunk block, and may be slotted. The tone is more complex than that of the Clarabella; less flute-like and hooting. It has somewhat the same relation to the Clarabella that the Violin Diapason bears to the Diapason.

Zauberflote—Harmonic Gedeckt, 8ft., 4ft.

The Zauberflote, introduced by Michell and Thynne (1885) is remarkable in being a stopped harmonic Flute. The pipes are of metal, pierced about one-third of their length from the top. As stopped pipes only produce the odd numbered partials, the first harmonic forms the interval of a twelfth to the prime, and is number 3 of the harmonic series. The basses of this stop, as usual in such cases, are not harmonic. The tone is distinct from the open Harmonic Flute. (See Harmonic Pipes.)

CHAPTER IX

PRACTICAL TUNING

The keyboard—The division of the organ scale—The perfect scale impossible—The devices by which pipes are tuned—Tuning cones—Testing for sharpness or flatness—Tuning and cleaning reeds—The part of a stop to start tuning on—Dust in reeds—Effect of temperature upon the pitch—Setting the pitch—A scheme for laying the bearings—On laying the bearings mathematically correct—On pipes "drawing" out of tune—Pipes upon enclosed sound-boards—Vox Celeste—Mixtures, Quintation stops, etc.—On tuning pedal pipes—Rough tuning—Tests—All organ pipes are under dilfferent conditions

LIKE every other part of the organ, the keyboard is the outcome of hundreds of years of patient evolution. In very early times the keys were large indeed, being made of a size suitable to be pressed down by the entire hand. With the progress of the art they became smaller and smaller and more convenient to use, culminating in the present-day forms In old organs, where pedals were not used, the keyboard projected but a few inches, as may be noticed in some old pictures. Even as late as the early part of the eighteenth century the keyboards on small instruments seldom projected more than six or eight inches from the front of the case and were generally made to slide in.

The keys—down to the present day—were generally made of ivory and ebony; although we have seen two sets of keys covered entirely with mother-of-pearl, the sharps being, as usual, of ebony; but such instances as this are rare. It is worthy of note that at one time this order of things was reversed; the sharps were of ivory, and the naturals were black, of ebony.

The division of the organ scale has exercised the minds of many

scientific organ constructors. In order to meet perfectly the requirements of music written in all modulations, the octave would have to be divided into something like thirty-five parts. Some of these notes, however, would approximate so closely in pitch as to render the employment of a much smaller number of notes compatible with the demands of harmony. According to one eminent authority, it is possible to adequately provide for all exigencies by employing twenty-four notes to the octave.*

Many attempts have been made to construct organs with the exact mathematical scale, but, on the whole, the complications introduced both as regards mechanism and the increased difficulties of execution, have counterbalanced any gain from a musical point of view.

The scale of the modern organ is, therefore, divided into twelve parts. Needless to say, this scale is far from correct. It depends for its existence simply upon the fact that it presents, comparatively speaking, few difficulties of execution.

If it were possible to construct a perfect scale for the organ, the harmonious intervals, such as fourths, fifths and thirds, etc., would be smoother and sweeter than they now are, owing to the absence of beats, but the dissonances would be correspondingly rougher and harsher. It is a matter of personal opinion, perhaps, whether harmony without beats is desirable, for a slight " wave " in sustained harmonies renders them less fatiguing to the ear; they are, so, more pleasing and acceptable; but all such considerations aside, the perfect scale of untempered intervals can never be anything more than a theory, were it only for this reason. That an organ will not stay " in tune " for any length of time. The relations in pitch of its many pipes to each other are varying ceaselessly, and must ever so do for as long as there are organs.

The present-day method of tuning, by which the tempered intervals are made available for all tonics, is the outcome of the demands of modern music.

* Helmholtz.

Formerly, when church music was written in but few keys, the intervals of the tempered scale were tuned in such a manner as to favour those keys. This method of tuning is called unequal temperament. The present-day music is written in all keys; therefore, the method of tuning known as equal temperament is in use. This method favours no special key, the dissonance inseparable from the tempered scale being distributed, as it were, over the entire octave (twelve semitones).

PRACTICAL TUNING

Most modern organ pipes, in order that they may be readily tuned, are fitted with either a clip or a tuning piece (see Plate 46). The clip is a cylindrical piece of thin iron, tin plated, which fits tightly over the end of the pipe. By knocking this up, the speaking length of the pipe is increased, the pitch being lowered, with the contraries. The tuning piece, in the case of a metal or zinc pipe, is a strip of metal which fits in a slot in the pipe. Opening this like a door, sharpens the pitch, closing it has an opposite effect. In the case of a non-stopped wooden pipe, a pedal Open Diapason, for instance, the slot in the pipe would be covered with a movable piece of wood (see Plate 46), or with a slide. All stopped pipes are tuned by means of the stoppers.

Pipes without clips or tuning pieces of any description are tuned with special instruments called tuning cones. These instruments consist of a solid and a hollow cone. They are of varying sizes to suit different pipes. The single cones, or "cups," are for large pipes. For tuning most of the up-to-date organs, very large tuning cups are not required, as the pipes below the Tenor C are generally equipped with some form of tuning piece. Two moderate sized cups are usually necessary, with four or five tuning cones. Before starting to tune, a little oil should be wiped over the cups and cones.

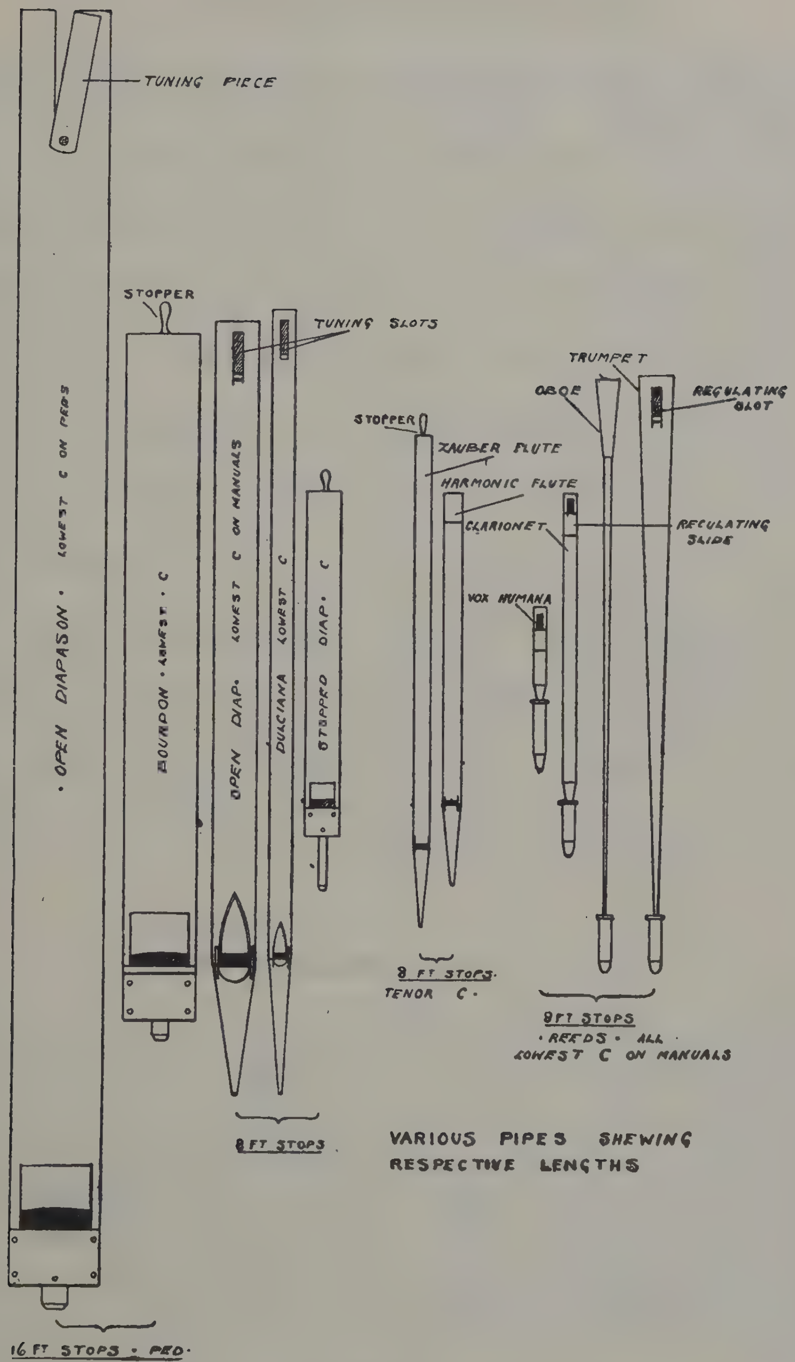

Plate 46

VARIOUS ORGAN PIPES, FLUE AND REED, SHOWING THEIR COMPARATIVE LENGTHS

The cones should be held lightly near the end, so that they may be quickly reversed. To test whether a pipe is sharp or flat, the pointed end of the cone should be cautiously approached to the top of the pipe. This has the effect of flattening the pitch, therefore, if the pipe is already flat, it will accentuate it, and if the reverse, it will beat less rapidly and perhaps come into tune. If it is desired to sharpen the pitch, the pointed end of the cone should be used; and if flattened, the hollow or cup end. When cupping a pipe, always use a cup on the large side; otherwise, if the aim is not true, the pipe will sustain considerable damage. Also a succession of taps is better than one or two heavy blows. To always ensure this succession, move the hand only from the wrist. When listening for beats, carefully keep the tuning instrument away from the pipe, so that it will not be influenced in any way. As far as possible, use only one hand for tuning. It will generally be found, in tuning any organ, that the pipes are singly and collectively out of tune in one direction. That is to say, they will be either slightly flat or sharp. When this is the case, it is mere waste of time to test each pipe in order to ascertain in which direction it has gone. As a general rule, all pipes are made sharper by increase of temperature, and flatter with a decrease.

TUNING AND CLEANING REEDS

Reeds are tuned by means of a spring which regulates the length of tongue (see Plate 43). Knocking the spring up, so lengthening the tongue, flattens the pitch; knocking it down, has, of course, an opposite effect. A long steel blade is the instrument generally used to tune reeds. It can be made, if desired, in two pieces of unequal length, with a screw joint. Three varying lengths of blade are then available. The clips or slots in the tops of reed pipes are for regulating purposes only, and should never, in the ordinary way, be used for tuning.

When tuning reeds it is not generally possible, or desirable, to shade the tops in order to ascertain in which direction the pitch has gone. They will generally be found to be either all flat or all sharp to the main body of flue-pipes. Having tuned several by experiment, the direction in which they are out of tune will be apparent, and the rest may be treated accordingly. As reeds, or indeed any pipes, come nearer and nearer to the pitch, the beats become slower and slower, until, when in tune, they finally cease. If the spring is knocked up or down past the position where the reed is in tune, the fact will be made obvious by the increasing rapidity of the beat. It is a very easy matter to tune any reed the difficulty being, having once tuned it, not to knock it out of tune again by incautiously endeavouring to reach neighbouring pipes.

It is usually advisable to start tuning a reed stop from the top note, and to work downwards. If there are several reed stops on one sound-board, the innermost should be the one selected to start tuning upon (after, of course, the flue-pipes have been tuned). By so doing, if any of the front ones are inadvertently put out of tune, it is of no consequence, as they yet await their turn.

Before tuning reeds, it will generally be found necessary to "regulate" a few notes here and there. Reeds are also very susceptible to the presence of tiny particles of dust upon the tongue. When dust is present, the reed either refuses to sound, or the tone is rendered harsh and "thin." To remove the dust, take out the pipe affected (if a bass note, simply remove the "boot," leaving the body in position, suspended from the support) and disclose the tongue. If the tongue is weighted, pull the spring against the wedge; if this is not the case, remove the spring by pushing it completely off the tongue, and turning it around, pull back until it is out of the way. Next obtain a very thin, tough piece of paper and insert it between the tongue and shallot (Plate 43) Put the thumb upon the reed tongue, and pressing lightly, draw out the paper, which will remove the dirt. Repeat this two or three times, or until the paper ceases to be soiled. Above all, do not alter

the curve of the tongue, and be extremely careful when replacing the spring. By holding the reed edgeways up to the light, the dust may sometimes be observed underneath the tongue.

After handling a reed, or indeed, any metal organ pipe, it should be left some time in order to regain its normal temperature. By tuning it a trifle sharp after it has been handled, it will usually be found to be in tune when cool.

Reeds, in common with flue pipes, are made flatter with a decrease and sharper with an increase of temperature. It is commonly believed that they are affected in a contrary manner, but that this is not so may be proved by anyone who is sufficiently interested to experiment. The flue-pipes, especially the metal ones, go out of tune in a body, in one direction; and as the reeds are not so readily acted upon by changes of temperature, they are left behind (if we may use the expression). If the temperature rises above that at which the organ was last tuned, the flue work generally becomes sharper. As the reeds are only very slightly affected, they are flat to the rest of the organ, so this has probably given rise to the belief that reeds become flat with an increase of temperature, and sharp with a decrease.

PITCH

We will suppose the novice desires to start tuning an organ. If the action is upon the tracker principle, the first thing to do is to make sure that the key touches, draw-stops, etc., are working correctly, and that the pallets are opening to their full extent. If the action is some form of pneumatic system, and the pipes are all sounding, the correct working of the pallets, etc., may be taken as a foregone conclusion. A steady supply of wind is essential. If the wind is supplied from a power installation, the supply should be steady, and unfluctuating in pressure; but if from manual power, it may, quite possibly, be neither. If this is unfortunately the case, the bellows should be pumped up to a

certain height, and kept there throughout the entire period of tuning, the blower moving the lever to its full extent, and at a uniform speed.

If the organ has not been tuned for some months, and it appears to be in a very dirty state the pitch pipe,* which is usually the middle C upon a 4ft. stop (the Principal)† should be very slightly sharpened, comparing it with a Diapason meanwhile. This should not be done to such an extent as to produce a beat, for the consequences would then be serious.

When dust accumulates in flue-pipes, it has the effect of flattening the pitch. The alteration is more perceptible in small pipes than in large ones, and, if the above hint is not acted upon, the tuner will be forced into unnecessary labour, and probably will have to "pinch in" the bass notes in order to flatten them sufficiently. If the difference in pitch is equal to $\frac{1}{32}$in. upon the length of the middle C, Principal 4ft., the additional length required upon the lowest C Open Diapason 8 ft would be, roughly, about $\frac{1}{4}$in. By keeping the pitch as nearly as possible up to its original standard, this flattening of the lower pipes, even if not obviated, is reduced to a minimum. In properly "finished" instruments, the flue-pipes are "coned in" to allow for this slight sharpening. In the course of years, the oft-repeated tuning brings the top out straight, and, if the pipes are to be kept undamaged, the organ should then be cleaned.

After the lapse of several years, it is usually useless to attempt setting the pitch pipe up to its original standard, as derived from a tuning fork; as, for the reason explained above, the pitch of an organ becomes slightly lower as the years pass on.

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* When an organ leaves the builder's factory, a "pitch pipe," suitably protected, usually accompanies it. When this is the case, the pipe selected is the one C, octave above Middle C, upon the stop Principal or Gemshorn 4ft. This pipe, termed the "6in. C," is selected as it is of a "handy" size, and may be easily sent through the post. From this circumstance the pipe in question has become identified with the term "pitch pipe," but, correctly speaking, the pitch pipe is the Middle C, or "foot C," an octave below the 6in. C, amongst English organ builders.

† Unless it be the Gemshorn, an octave Diapason is the pitch stop, thus: the Octave, Principal, or Geigen Principal 4ft.

True, the alteration is in some instances very slight, but any serious attempt to retain the pitch up to its primary source can only result in more labour, and in the occupying of more time, than the end justifies. That is, as regards the periodic tunings. When the pitch alters perceptibly, and the reeds lose their original excellence of tone, the organ should certainly be cleaned. But this is, of course, outside the scope of the ordinary tuner's visit.

Having settled with the pitch pipe, and providing the "regulation" is right, i.e., no conspicuous loud or soft notes, the tuner may now proceed to lay the scale, or lay the bearings, as it is alternatively termed.

LAYING THE SCALE

As the veriest tyro knows, when two pipes are out of tune with each other, beats are the result. The more they are out of tune, the more rapid the beats, until, if the difference be very great, the beats cease to appeal to the ear as separate pulses, but give rise to an unpleasant roughness of tone. In other words, out of tune means dissonance, and perfect tune is synonymous with perfect harmony (harmony without beats).

In an organ, the only interval that is in perfect tune is the octave.* Every other interval, as, for instance, the fourth and fifth, is, in a varying degree, out of tune.

Stops such as the Twelfth, Quint, etc., are tuned perfect to the pitch, i.e., without beats. By this means, the resultant tones produced reinforce the primary tones perfectly, as they are harmonious with them. If they were not tuned perfect, the resultant tones would, of course, cease to be in perfect harmony, and their full effect would be lost.†

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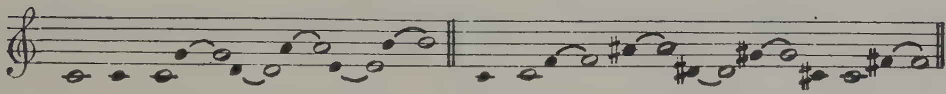
* And, of course, that which cannot be termed an interval, the unison.

† The twelfth is not introduced primarily for the purpose of creating difference, or any resultant tones, but to augment the natural harmonic of like interval. The Quint sometimes is intended to create difference tones, as in the stop Acoustic Bass.

The following is a scheme, in almost universal use at the present time, for laying the scale in equal temperament. The fifths are tuned a little flat, and the fourths sharp; the degree of flatness or sharpness is obvious by the frequency of the beat.



If the scale is correctly laid, the B natural should be sharp to F sharp and flat to E. The amateur is not advised to practise laying scales upon pipes he values, as first attempts are usually unfortunate. It will be found expedient, when first attempting to lay a scale, for the one at the keys to dictate, while the would-be tuner flattens or sharpens the pipes as informed.

The above method of laying the scale, reduced to writing, is as follows:

Middle C on the Principal 4ft. as pitch. Hold the C and G together, and tune the latter note flat until a slow beat is discernible. Then hold the next note, D, to the G, and tune the D flat, the beat to be quicker than the last Then tune the A to D, tuning the A flat; next tune the E to A, the E flat; B to the E, the B flat. The beat must be quicker in the interval of a fourth than in that of the fifth.

Now return to the middle C and tune the F to it, this time sharp; then the A♯ to the F, the A♯ sharp; the D♯ to the A♯, the D♯ to be tuned sharp; theG♯ to D♯, the former sharp; C♯ to G♯, the C♯ sharp; and then the F♯ to the C♯, the former to be tuned sharp.

If correct the B natural should be sharp to the F♯ and flat to the E, which ascertain by holding the point of the tuning cone to its top. If it is not correct, go carefully over the scale and find out where the beats have been made too quick or too slow.

The best result to be obtained from the tempered scale, for all modulations, would be when the bearings were laid with mathematical exactitude. Most practical tuners say, however, that it is impossible to

so lay a scale, as different stops of pipes, and nominally, the same stops of pipes upon different instruments, exhibit a varying frequency of beat for the same degree of aberration from a pitch common to all. We do not vouch for the accuracy of this statement, but it appears to be the conclusion arrived at by a great many organ tuners, whose opinions, qualified as they are by years of practical experience, merit some consideration.*

Having successfully laid the scale upon the middle octave, the C above middle C, if this has not already been done, should be tuned to it. Then proceed in octaves, tuning the upper note to the lower one, and so on until the top note is reached. Then, as the tuning proceeds downwards, test the lower note by holding it to the fourth and fifth above. If correctly tuned, it will be flat to the fourth and sharp to the fifth.

When two notes are sounded together whose vibrations are the same, or are to each other as the ratios 1 : 2; or in other words, any two notes in unison, or one note and any octave above or below—they have a tendency to "draw." That is to say, if one is slightly sharper or flatter to the pitch of the other when sounded alone, when combined together they will be found to be in tune. The power a note has to "draw" varies with its loudness, but all organ pipes exhibit this peculiarity in some degree.

When tuning the pitch stop, therefore, it must be tested by fifths and fourths in order to ascertain whether it has drawn into tune before it is yet perfect. If it answers to the above test—which may be easily determined by shading the pipe with the hand or a tuner—it may be passed. If it does not, it should be altered slightly, in the required direction and tested until found correct, without, of course, producing the slightest perceptible beat when it is held to the octave. It is only usually necessary to tune the pitch stop in this manner, and even in that

* This apparent departure from the laws of acoustics may be due to the phenomenon of "drawing."

stop it will be found impractical to tune more than a few notes above the middle octave in this way, on account of the increasing rapidity of the beats as the scale ascends. But below the middle octave it should be tuned down to the lowest note in the manner explained, i.e., testing by fifths and fourths.

Having tuned the pipes up to the top note, return to middle B, and hold B, octave above, with it, proceeding downwards in octaves, tuning the lower note to the higher one, and testing as before by fifths and fourths. It will usually be found convenient to tune one "side" at a time. That is to say, as the pipes are arranged on the sound-board—first C, D, E, F♯, G♯, A♯, C, etc., and the return to the C♯ side and tune C♯, D♯, F, etc., and so on, downwards.

Having tuned the pitch stop, the others should be drawn, one at a time, and tuned in unison with it, beginning at the highest note and tuning down to the bass in sides.*

The stops are arranged upon the sound-board to facilitate tuning, so usually, it will be found possible to begin upon the one furthest away, thus minimising the risk of disturbing pipes already tuned by leaning and reaching over them.

Avoid, as far as possible, touching or lifting out the pipes. If, for some reason it is necessary to handle them in order to rectify some defect of "speech," allow them to regain their normal temperature before finally tuning them. Also, always replace a pipe facing in the same way as originally disposed by the builder—with a free, unoccupied space before the embouchure.

Upon the various separate manuals it is necessary to lay a complete scale; but, if possible, all the stops after that should be tuned to the pitch stop. Sometimes, however, this is not possible. Small scaled stops, of soft intonation, are liable to "draw" very much into tune while they are yet several beats out. The only way to successfully

* It is, perhaps, preferable to tune from Middle C as a centre, first ascending to the top note, and then descending to the bottom note.

overcome this obstacle, is to lay a separate scale upon the stops that are bad offenders in this respect, tuning them throughout in a similar manner to the method observed with the pitch stop.

UPON TUNING PIPES UPON ENCLOSED SOUND-BOARDS

When setting the pitch upon an enclosed sound-board, as in a swell box it should usually be kept a trifle sharp to the other manual, or manuals, as the temperature, when tuning, is usually below that when the organ is used for services, etc., and alterations in temperature are retarded by the protection of the box.

Do not remove more shutters than are rendered necessary for easy access to the pipes When tuning the front stop, if a reed, the shutters should be replaced, and the tuning accomplished through the space left by the removal of the tuning flaps. The reason for this is that the stop, coming close up to the shutters, may possibly be "shaded" by them. It will generally be found best to tune pipes upon enclosed sound-boards first; and, the tuning finished, to replace all shutters, etc., leaving the shutter action open. In all cases, when the organ is not in use, the crescendo box should be left open.

VOX CELESTE

The above-named stop, and all stops from which is produced an undulating, waving effect, when in combination with another stop, are tuned either a trifle sharp, or a trifle flat, to the stop with which they are used.

When tuned sharp, the beat is a little quicker, for the same degree of deviation from the pitch than when tuned flat.

In order that the stop may be, as nearly as possible, the same degree out of tune throughout, the wave, or beat, is made to become gradually quicker as the scale ascends.

MIXTURES, QUINTATON STOPS, ETC.

The above-named stops, or, indeed, any stop which forms an interval other than an octave with the pitch stop, should be tuned perfect. In a Mixture, where several ranks are sounding together, it is the practice to silence all those except the one upon which the tuner is engaged. This may be done by thrusting a wad of raw-cotton (cotton wool) into the end of the pipe; or by little cups or cylinders constructed for the purpose. The former is perhaps the best method, as the cotton does not disturb the top of the pipe.

PEDAL PIPES

As a sound approaches the limit of hearing, in either direction, it becomes increasingly difficult to hear the beat. The limit varies with different individuals, some people being able to interpret as a sound a much lower, or higher, vibratory rate than others. When tuning pedal pipes it will be found best to begin at the highest note, as upon the manuals, and work downwards. They should be reserved until the last, and the 16ft. stops tuned to the manual Open Diapason on the Great.

If, for some reason, it is difficult to detect the beat, after the first octave of pipes have been passed, the tuning may be continued by holding octaves upon the Pedal Organ alone.

In the ordinary way it is not necessary to tune the Pedal Organ, as the variation from the pitch, even in the course of years, is practically negligible. That is upon the flue-stops of 16ft. tone and over. Pedal reeds require to be kept in tune to the rest of the Pedal Organ, but even with them, the difference is not so great as upon the manuals.

ROUGH TUNING

Sometimes an amateur, in the absence of a qualified tuner, finds it necessary to "run through the reeds."

In order to do this effectually, it will generally be found necessary to roughly tune the pitch stop, as nothing is gained by tuning reeds to a pitch which is, in itself, already at variance.

To do this, test the upper part of the stop in octaves. If a note here and there is badly out, make sure you have the right one by holding its octaves above and below as a test, and then tune it to its octave below, if this is in tune. If, for some reason, you suspect it is not, test it to its octave below again; this will generally be a safe test, as the notes below the 2ft. C do not vary much. Having picked out any very bad notes there may be, tune from middle C, upwards in octaves. The reeds may then be tuned to the pitch stop.

TESTS

Having tuned an organ throughout, it should be tested by holding octaves, with the "full organ." (Excepting, of course, such stops as Mixtures, which are not tuned in equal temperament.)

If, as stops are gradually added, notes here and there unaccountably go violently out of tune, robbings may be the cause. (A pallet insufficiently opened may also be the cause.)

By trying the effect of adding and subtracting various stops, the cause may be located, and palliated, to a certain extent, for it is impossible to cure it. In the generality of cases, a compromise will be found the most bearable. That is to say, the note or notes, should not be in perfect tune when the robbing is absent, nor in perfect tune when the reverse is the case, but in tune midway.

All the stops in an organ are never perfectly in tune with each other at the same time. The pipes are so widely separated, that changes of temperature cannot affect them equally. Also, it is not exceeding the truth to say that every "stop" in an organ is under different conditions to its neighbour. Still strictly adhering to the truth, we may say that each and every *pipe* is, in some way, under conditions

peculiar to itself; so we see it is no cause for wonder when an organ "goes out of tune."

Flue work should be tested first by playing chromatically in double octaves. This is a severe test with reeds. One manual at a time should be tested in this way first, and then coupled. By adding and subtracting stops to the pitch (Principal, Gemshorn or Octave or 4ft. Geigen, as the case may be) defects may be localised.

(See "Modern Organ Tuning, the How and the Why," by Hermann Smith, which deals fully with the subject.)

APPENDIX A

NOTE TO PAGE 35—A great amount of uncertainty attaches to the beginnings of the modern organ. Even if the facts were clearer than they are it would be a questionable statement—or, at least, one not in accordance with the "whole truth"—to say: "This man invented bellows ribs," or, "Such a one invented swell boxes"; for such inventions are generally the outcome of accumulated ideas, passed from one man to another, to be dismissed by some, pondered over by others, and by a few acted upon. Even when the idea eventually takes a more material form than thought, it (the form) is crude and imperfect, and is left for succeeding generations to improve and improve again.

For the following facts we are indebted to Messrs. Hopkins and Rimbault from their work on the organ:

"The idea" (of the inverted ribs) "was first sketched out" by a clockmaker, of the name of Cummings, in the year 1762, and was "carried into practice" in 1787. After hinting that Cummings's invention was unreliable, our authors proceed:

"The one main fact, at any rate, is certain, as well as satisfactory, namely, that the horizontal bellows" (double rise bellows with inverted folds) is an invention of English origin."

Flight, the organ builder (born about 1767), is credited with having first applied the idea in a satisfactory way.

APPENDIX B

NOTE TO PAGE 5—The exact date is uncertain. Messrs. Hopkins and Rimbault write:

"The first idea of establishing such pneumatic assistance occurred to the late Mr. Joseph Booth, organ builder, of Wakefield, who applied his invention to the organ he built for the church at Attercliffe, near Sheffield, in the year 1827."

"It was left, however, for Mr. Barker, a native of Bath," to develop the idea further, possibly in the year 1832. Mr. Joseph Booth's idea was only a "pneumatic assistance," being a small motor or "puff" aiding the ordinary tracker action.

APPENDIX C

COUPLING AND BORROWING

The supplementary matter here introduced on the subject of tubular coupling includes a description of a method wherein neither check valves, fly pallets nor membranes are required; further, it is adaptable for effecting what is known as "borrowing," or—more euphuistically—"deriving." These terms may be defined as meaning "localised coupling," such as an arrangement whereby a stop belonging to one department of the instrument becomes available in another, as, for instance, a Swell Double, in addition to its primary use may be operated from the Pedal Organ, thus—in effect—adding a stop to that department. A stop of pipes so "derived"—by any method—cannot be controlled by a slide or ventil, in the usual way, and in consequence must be set apart from a main sound-board, control being effected through the action.

The coupling arrangement consists of a special adaptation of a three-motor auxiliary machine, in which the secondary motors (outside, in this case) are duplicated in sets—one set for the main, and one set for each coupler—and arranged on "shelves" under the bottom-board of the sound-bound. The main motors under the pipe pallets are fixed to the bottom-board and controlled by "inside" valves which, when lifted, exhaust them. This arrangement may be symbolised thus (see diagram, Fig. 1):

A
B
C

The letter C represents one secondary motor, a main; B represents another for the purpose of coupling; A similarly as B. A median line drawn from A to C would represent a long tapped wire on which the valve previously mentioned is attached at the top; in practice this would pass through arms on motors A, B, to the arm on motor C. A single button *above* each arm permits

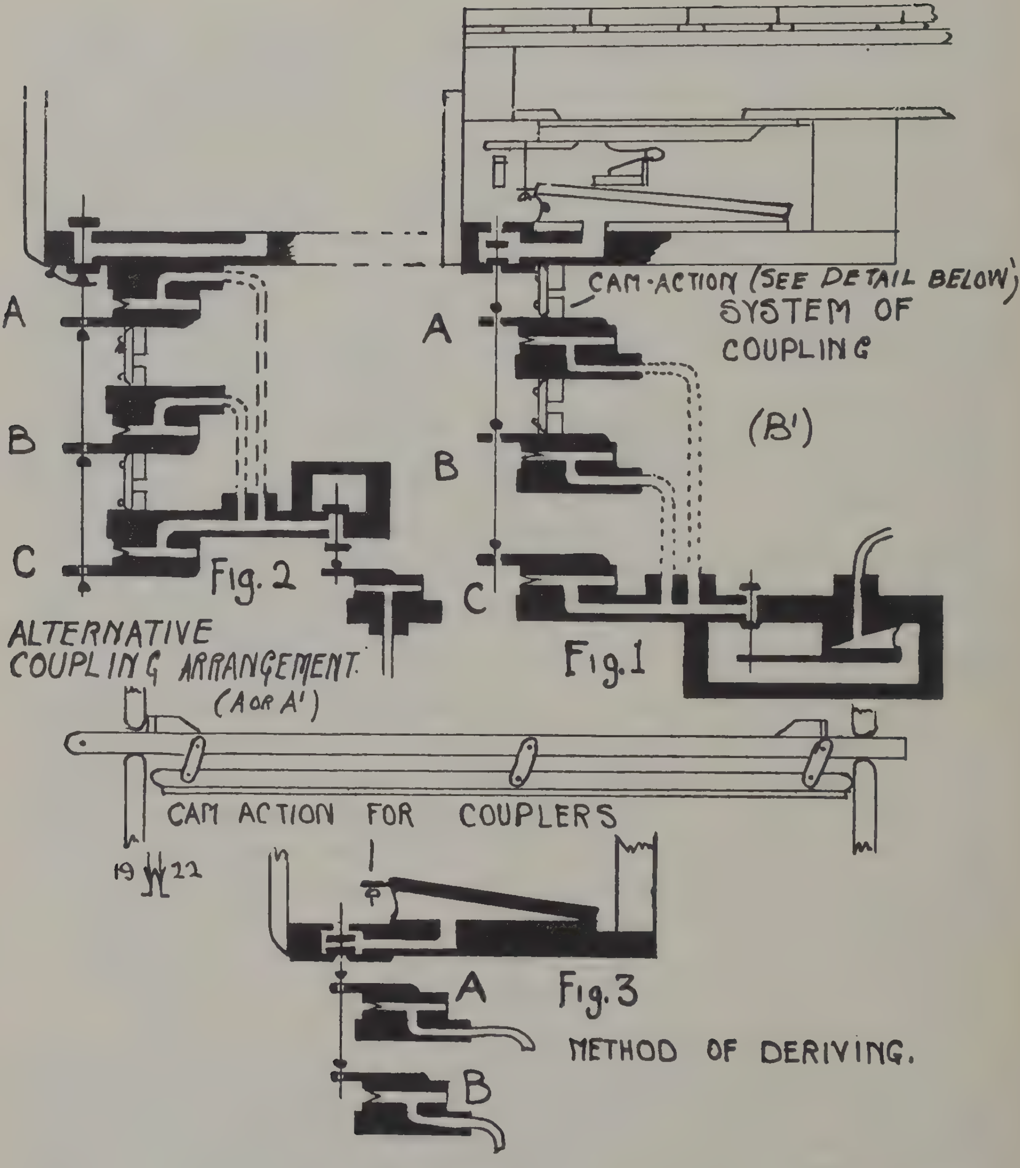


Plate 47

DIAGRAM ILLUSTRATING A METHOD OF COUPLING AND "DERIVING."—FIG. 1. COUPLING, EXHAUST SYSTEM. FIG. 2. COUPLING, SUPPLY SYSTEM. FIG. 3. METHOD OF "DERIVING"

of the valve being lifted by any motor independently, or by any combination of the three. Secondary motor C is controlled in the usual way from an initial small valve and actuating motor (auxiliary motor, so-called herein) which is exhausted or supplied from the key action after the manner explained in the foregoing pages. The action-box containing this auxiliary motor may be arranged to suit any tubular system (A, A^1 or B^1, as already referred to). The duplications of the secondary motor C, A and B, are controlled by the auxiliary valve and motor, being supplied through tubes from the same source as motor C. In the original form of this action, used some twenty-five to thirty years ago, the coupling motors were supplied directly from the key action, together with the main motor, following the method of early tubular work before the introduction of an auxiliary.

The manner in which the motors A and B are tubed determines the coupling, thus :

A,	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13, etc.
B													13, etc.
C,	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13, etc.

The row of numerals from C represent thirteen out of the total of sixty-one—when that is the key compass—*main* secondary motors. These are free to lift when supplied, and may be placed directly on a boring from the auxiliary valve. If the numerals represent semitones, a tube from the groove which supplies motor C^1, taken into motor B^{13}, will effect octave coupling. Similarly, a tube from C^{13} to A^1 would, on the assumption that number 1 is the bass end of the scale, effect sub-octave coupling.

To complete this scheme some mechanism under control of the coupler draws is essential, otherwise the coupling would be permanent. There are several ways of accomplishing this : we mention two. (1) The coupling tubes may be intercepted by a slide ; or preferably (2) a cam action, similar in design to a draughtsman's parallel ruler, may effect the rise and fall of a light beam —a lath of wood—on the tops of each set of coupling motors to shut them off when not required.

With this system a "Unison Off" may easily be arranged by bringing the main set of secondary motors under control of a draw knob, similarly as with the octave and sub-octave coupling motors. The accompanying sketch diagram (Fig. 1) is intended to illustrate this method of coupling. An alternative arrangement is also shown (Fig. 2).

The following explains the example of "borrowing" given with the open-

ing section of this Appendix. We may note in passing that although it is necessary to particularise for the purpose of explanation, any stop may be so "borrowed" by this method if set apart from a main on to a pneumatic "off note" sound-board. But in the instance selected—and also with an enclosed Choir Double—objection to "borrowing," as such, may be waived, as there is no other reasonable means of obtaining a soft pedal stop under control of the swell pedal for use with quiet Swell combinations.

To explain this borrowing we may proceed (as with the coupling), thus (see diagram, Fig. 3, A, B):

These letters represent two motors, as before explained, connected to one wire. As it is usual to employ "two motor type" actions with off note sound-boards (as, generally, with pedal sound-boards), motor B may be tubed from the Swell sound-board through a slide in the way usual; motor A may be supplied from a relay machine under pedal control: in this way the Swell Double* would come under control by means of the stop action working the slide, and the derived Pedal Stop (Echo Bourdon, usually so called), could be controlled by means of a small ventil which could supply and exhaust the relay: in any case the action, and not the sound-board, is the means whereby the stop is controlled.

There are other methods of control to these; the cam action mentioned in connection with the coupling arrangement might be utilised—obviously, possible modification in detail are not less numerous than is generally the case with organ mechanism. We refer readers to the sketch diagram.

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* The lower portion of a "Swell Double"—16 ft. Diapason—is not unusually of stopped wood pipes, virtually a Bourdon of small scale: hence, when derived, "Echo Bourdon."

APPENDIX D

MAIN MANUAL SLIDE SOUND-BOARDS AND AUXILIARY MACHINES

The setting out of manual slide sound-boards is a complicated undertaking to which there is really only one key, viz., experience. It is possible, however, to evolve from experience some guiding principles which lead to a certain amount of standardised practice, as the following is intended to show.

In the case of large organs the various pressures necessitate the location of the stops upon several sound-boards, so it is seldom necessary to provide for more than ten stops per sound-board. This also applies to moderately large and small organs having pipes winded on a uniform pressure.

The economy of planting twelve or even more stops on one sound-board may be attended with no counterbalancing and resulting fault—such as "robbing"—for very much depends upon the character of stops so planted. Therefore, whilst according to circumstances, more than ten stops may be planted upon one sound-board without any detriment, nothing can reasonably be urged against a canon which, if followed, would divide them upon two sound-boards, except increase of cost.

If a sound-board be scaled to an 8 ft. 6 ins. rod, a safe dimension for length of main pallets may be arrived at by allowing 1 in. per stop up to a maximum of 10 ins., with a minimum length of 5 ins.. To make this clear, 10 ins. would provide for ten stops, 8 ins. for eight stops, but if a less number than five were required, the pallet should not be shorter than 5 ins.

In making this allowance it is assumed that no builder would now plant 16 ft. basses upon, or wind them from, a main manual sound-board. With 16 ft. basses on separate wind, a sound-board length of 8 ft. 6 ins. meets all normal requirements, and allows sufficient room for pneumatics. We may point out that an 8 ft. sound-board is considered by many builders to be an ample allowance. Sound-board length in excess of 8 ft. 6 ins. is not, necessarily, for the increase of width of wind spaces between bars, but may be for increase of

room for planting pipes, accessibility for tuning, or advantageous use of space available for building. While we cannot expect to cover all possible requirements by prescribing one invariable length of sound-board, under normal conditions 8 ft. 6 ins. allows a safe working margin.

Where pipe and action wind are equal, a safe proportion of area of top of main motor is twice that of the pallet, the motor being leathered to open one inch without strain. If pressures are unequal, the area of motor top may be reduced to maintain the motor pull, considered as pressure on the top of the motor, in the proportion of 2 : 1. In no case will action wind be lower in pressure than pipe wind.

It is obvious that the dimensions of the motors in an auxiliary machine, particularly in the case of the smallest set, must be such as to give a satisfactory repetition within the range of wind pressures generally available. This, alone, necessitates limitation of the size of the largest main motors, and consequently of the main pallets. Thus, considerations other than those mentioned at the beginning of this section, which concerned the winding of pipes, indicate the same result.

The following tabulated dimensions of valves, motors, etc., proceed from the foregoing rationale. They may be used with a pressure as low as $3\frac{1}{2}$ ins., and any auxiliary machine herewith illustrated may be constructed. in accordance.

DIMENSIONS IN INCHES OF VALVES, ETC., FOR MANUAL AUXILIARY MACHINES

Number of	Valve holes	Valves	Motors	Valve holes	Valves	Motors
12	$\frac{3}{4}$	1	$1\frac{1}{4} \times 3\frac{1}{2}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{7}{8} \times 2\frac{3}{4}$
12	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{8} \times 3\frac{1}{2}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{7}{8} \times 2\frac{3}{4}$
12	$\frac{1}{2}$	$\frac{3}{4}$	$1 \times 3\frac{1}{2}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{7}{8} \times 2\frac{3}{4}$
12	$\frac{7}{16}$	$\frac{11}{16}$	$\frac{15}{16} \times 3\frac{1}{2}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{7}{8} \times 2\frac{3}{4}$
13	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{7}{8} \times 3\frac{1}{2}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{7}{8} \times 2\frac{3}{4}$
61 notes.						

Main sound-board pallet opens $\frac{5}{16}$ in.
Secondary valve opens $\frac{1}{8}$ in.
Initial valve opens $\frac{3}{32}$ in
Main sound-board motor opens 1 in. (without strain).
Remainder (if inside motors) open $\frac{3}{4}$ in. (without strain).

DIAMETERS IN INCHES FOR BORING UPPERBOARDS

Pipe	16 ft. C	8 ft. C	4 ft. C	2 ft. C	1 ft. C
Double Diapason (metal)	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	
Open Diapason		$\frac{7}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$
Principal			$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$
Fifteenth				$\frac{3}{8}$	$\frac{1}{4}$
Dulciana, Gamba, Salicional, etc.	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	
Stopped Diapason		$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	
Reeds	$\frac{3}{4}$	$\frac{9}{16}$	graduated to		$\frac{5}{16}$

The above are diameters in ordinary use. The diameter of the wind hole for any pipe depends principally upon its length and scale. In any case, it should be larger than the bore in the foot. Holes in slides and table are always made larger than the ones corresponding in the upper boards, and in no case is it well to bore any wind holes in the slides and table smaller than $\frac{1}{4}$ in., and for an 8 ft. Diapason none less than $\frac{5}{16}$ in. Circular holes in the upper-boards are tapered from the underside when singeing to meet the holes in the slides.

As the draw of the slides—$\frac{3}{4}$ to $\frac{7}{8}$ in., according to length rod—determines the amount of cover available, it is not usual to bore circular holes through slides and table larger than $\frac{9}{16}$ in. Where windways are required larger they should be slotted in the direction of the width of the slide, and corresponding slots made through the upper-board with a veneer to take the circular foot-holes.

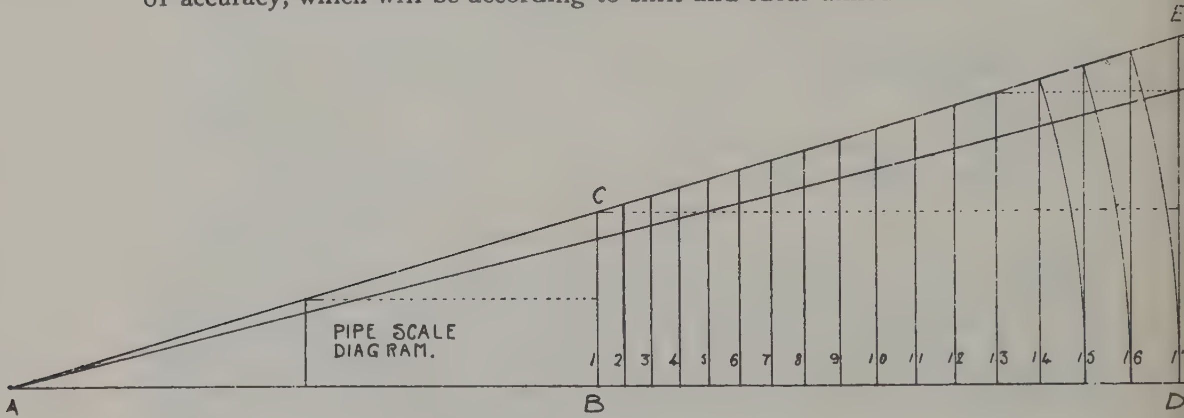
BARS, TABLE, ETC.

Depth of bars, for ten stops, 4 ins.; minimum, 3 ins.
Table. $\frac{3}{4}$ in., finished about $\frac{5}{8}$ in.
Slides, $\frac{3}{16}$ to $\frac{1}{4}$ in., finished (best thin).
Upperboards, minimum finished thickness, $1\frac{1}{8}$ in.
Rackboards, $\frac{5}{8}$ to $\frac{1}{2}$ in., finished.

PIPE SCALES AND LENGTHS

These remarks and particulars are directed, mainly, to meet the request of some readers who wished to make wood pipes, and expressed surprise at the omission of such scales from the previous edition.

The most convenient form of scale is a working diagram of actual sizes; this allows of accuracy to fractions, which, expressed by figures, would appear unimportant, and leaves the would-be pipe maker free to work to his own degree of accuracy, which will be according to skill and ideal aimed at.



A method of working out a scale suitable for the purpose of making wood (or metal) pipes, on the canon of halving at the seventeenth pipe, is here given.

To construct the above figure:

AB = $9\frac{3}{4}$ in. (or AD = 2 × $9\frac{3}{4}$ in.)
BC = $2\frac{7}{8}$ in. (or DE = 2 × $2\frac{7}{8}$ in.)
Connect ACE.

With radius AD describe an arc towards E, and from the point at which the arc intercepts line AE, drop a perpendicular to line AD. Seventeen arcs and perpendiculars may thus be obtained from DE to BC, the latter being equal to the half of the former: the perpendiculars 2 to 16 give the proportional decrease of the scale in between: these are, for metal pipes, diameters.

In order to obtain a scale for an entire stop—30, 58 or 61 notes as required—the diagram may be developed further by the same process from B towards A, or extended in the opposite direction from D, until the perpendicular of the required longest length is reached. There are several other methods of developing and using this diagram which will appear upon examination to those familiar with the drawing board.

In the case of cylindrical metal pipes, diameters only are required: these may be derived from the perpendiculars.

In the case of rectangular wood pipes not square, each perpendicular must give two dimensions, viz., width—which is also the width of the mouth, and

nearly always the smaller dimension—and depth, which is measured from the front of the pipe to the back. These, depth and width, are internal dimensions, and denote the size of the block upon which a pipe is constructed: the *external* dimensions of a pipe are therefore equal to the width and depth of the block, plus the thickness of the back, front and sides.

To use the scale for the construction of wood pipes of two unequal dimensions:

Let DE = depth of the block of the largest pipe required.

Let DF = width of the same.

The remaining perpendiculars give the proportional decrease of *widths and depths.*

Line AF is arrived at in the way shown on the diagram. The widths may thus be five perpendiculars, or more, or less—as required—smaller than the depths.

A 6 in. Open Diapason (8 ft.) scaled on this system of "halving at the seventeenth" would have the successive C pipes of the following diameters:

CC diameter 6 ins.	1 ft. C diameter 1¼ ins.
Ten. C diameter 3½ ins.	6 in. C diameter ¾ in.
Mid. C diameter 2⅛ ins.	

Without going into decimals, these figures are practically accurate. The weight of a Diapason made to this scale, bass included, might be 4 cwt. Such scaling and weight, however, are indicative of a high standard.*

As complete scales for making pipes cannot be properly expressed in figures without fractions which practical workmen would consider absurd, we merely give some dimensions of C pipes. Further, as scaling is relative to many factors, already mentioned herein, there can be no absolute standard. The *lengths* given were taken from actual pipes, and, in this connection, the "accuracy" of the scientist cannot be expected, for one good reason only, it does not exist except in theory.

In making wood pipes it is customary to allow a good margin for trimming off and cutting in tune, but it is advantageous to finish closer to speaking lengths with stopped pipes for the convenience of fitting stoppers. Wood pipes should be slightly convex, tested by a "straightedge," or, in the case of small ones, unerringly true. The joints should on no account be planed concave. Nails are not used in glueing up wood pipes until the 4 ft. length or thereabout has been exceeded. Small wood pegs are used to hold the front and back of each

* Actual weight must, however, depend upon: (1) scale; (2) system of scaling; (3) tone required; (4) composition of metal.

pipe in position whilst (after being glued) it is bound tightly with coarse string; this is then wetted to cause it to contract, and so pull up the joints. It is perhaps unnecessary to add that the joints must be perfectly air-tight.

SCALES AND LENGTHS OF WOOD FLUE-PIPES

Wald Flute (inverted mouth), Mid. C, $1\frac{5}{8}$ (mouth) $\times$ $1\frac{3}{4}$.

Clarabella, Mid. C, $1\frac{3}{4} \times 2$, to $1\frac{5}{8} \times 1\frac{3}{4}$.

The above two stops are continued down with a stopped bass, and, to prevent the break from open to stopped pipe becoming too audible by the change of tone quality, the stoppers in the upper part of the bass are pierced. It is preferable to continue the open pipes down to about G in the tenor octave—sometimes G sharp or A is selected. Clarabellas have been continued down to CC with open pipes, but the gain from a tonal point of view, owing to natural limitations, is nil.

In the case of the Hohl Flute there appears less uniformity of treatment or scaling. It may be scaled as a Clarabella or a Wald Flute. We mention elsewhere in this book that T. C. Lewis constructed Hohl Flutes with the mouths on the wider sides of the pipes, but it was not pointed out that the builder named did not use wood pipes above B of the tenor octave, this treatment therefore concerns the stopped bass only. Some prefer to halve the scale of the Hohl Flute at the twentieth pipe.

Stopped Diapason, CC, $2\frac{3}{4} \times 3\frac{5}{8}$ to 4×3.

(1). Bourdon, CCC, $4\frac{3}{4} \times 5\frac{3}{4}$ (nothing smaller should be used).

(2). Bourdon, CCC, $5\frac{3}{4} \times 6\frac{3}{4}$.

(3). Bourdon, CCC, $6\frac{3}{4} \times 7\frac{3}{4}$ (fairly heavy scale).

Pedal Open Diapason, CCC, 12×13 (fairly heavy scale).

WALD FLUTE lengths in inches measured from pipes cut to tune with the usual metal shade, scale and pressure as given. The measurements are from top of block to top of pipe.

Mid. C,	1 ft. C,	6 in. C
$21\frac{3}{4}$	$10\frac{1}{2}$	$4\frac{1}{2}$
$20\frac{5}{8}$	$9\frac{7}{8}$	$4\frac{1}{8}$
$19\frac{1}{2}$	$9\frac{1}{4}$	$3\frac{7}{8}$
18	$8\frac{3}{4}$	$3\frac{1}{2}$
17	$8\frac{1}{8}$	$3\frac{1}{4}$
16	$7\frac{1}{2}$	3
$15\frac{1}{8}$	7	$2\frac{3}{4}$
$14\frac{1}{4}$	$6\frac{1}{2}$	$2\frac{1}{2}$
$13\frac{3}{8}$	$6\frac{1}{8}$	
$12\frac{5}{8}$	$5\frac{3}{4}$	
$11\frac{3}{4}$	$5\frac{3}{8}$	
11	5	

SCALE

Mid. C $1\frac{5}{8} \times 1\frac{3}{4}$

1 ft. C $\frac{7}{8} \times 1\frac{1}{8}$

Top G $\frac{9}{16} \times \frac{5}{8}$

Pressure $3\frac{1}{4}$

Diapason Normal Pitch

(Owing to the tuning shades, these lengths are, by the equivalent of a semitone, shorter than speaking lengths).

STOPPED BASS for foregoing stop, measurements in inches. Lengths with surplus for tuning by stoppers.

CC, 45½	—Ten. C,	23¾	
43	... ...	22½	
40¾	... ...	21⅜	
38	... ...	20	
36	... ...	19	Pierced stoppers
34	... ...	18	Pierced stoppers
32¾	... ...	17	Pierced stoppers
31¼	... ...	16	Pierced stoppers
29¾	... ...	15¼	Pierced stoppers
28	... ...	14½	Pierced stoppers
26¾	... ...	13½	Pierced stoppers
25	... ...	12½	Pierced stoppers

SCALE
CC 2¾ × 3⅝

BOURDON lengths in feet and inches, measured from top of block to top of pipe inclusive of overlength for tuning by stopper. Scale A, as given, is from measurement of a good stop which furnished the lengths; scale B from the method given a few pages preceding.

	ft.	in.		ft.	in.		ft.	in.
CCC,	7	9½	—CC,	3	10	—C,	1	11¼
	7	4	...	3	7	...	1	10
	6	11	...	3	4½	...	1	8½
	6	6	...	3	2	...	1	7
	6	2	...	3		...	1	6½
	5	9	...	2	9¾	...	1	5½
	5	6	...	2	8			
	5	2	...	2	6			
	4	11	...	2	4¾			
	4	7½	...	2	3¼			
	4	4	...	2	2			
	4	0½	...	2	0½			

SCALE A
CCC, 6⅝ × 7¾
CC, 3⅞ × 4⅞
C, 2$\frac{1}{16}$ × 2½

SCALE B
CCC, 6⅝ × 7¾
CC, 4 × 4¾
C, 2⅜ × 2¾

Pressure 3¼
Diapason Normal Pitch

OPEN DIAPASON (Pedal) lengths, measured from top of block to top of pipe. These pipes were tuned by means of shades inside the top. If tuning slots are required, length must be added to each pipe.

	ft.	in.		ft.	in.		ft.	in.
CCC,	14	2	—CC,	7	0	—C,	3	4½
	12	11	...	6	6	...	3	2½
	12	4	...	6	1½	...	3	0½
	11	7	...	5	8	...	2	10
	11	1	...	5	4	...	2	8¼
	10	5½	...	5	0½	...	2	6
	10	0	...	4	10½			
	9	3	...	4	6			
	8	9	...	4	4			
	8	5	...	4	2			
	7	8½	...	3	10½			
	7	6½	...	3	8			

SCALE
CCC, 12¾ × 13¾
CC, 6⅛ × 7⅛
C, 3⅜ × 4⅛

Pressure 3¼
Diapason Normal Pitch

N.B.—As exact tunable lengths of pipes cannot be predetermined, in making wood pipes overlength to the equivalent of a semitone should be left on each pipe for the purpose of "cutting down" to the pitch.

6 IN. OPEN DIAPASON BASS, AND 4 IN. DULCIANA BASS (METAL)

The following information is tabulated for guidance in designing organ cases and pipe work therein. The lengths are speaking lengths, so that less may not be allowed, but overlength for decorative effect may be added. For the feet, 18 ins. for CC is a good proportion.

	Diameter in inches	Length		Diameter in inches
Open Diapason, CC,	6	7 ft. 11 ins.	Dulciana	4
	$5\frac{3}{4}$	7 ft. 6 ins.	... ...	$3\frac{3}{4}$
	$5\frac{1}{2}$	7 ft. 1 in.	.. ...	$3\frac{5}{8}$
	$5\frac{1}{4}$	6 ft. 8 ins.	... ...	$3\frac{3}{8}$
	5	6 ft. 3 ins.	... ...	$3\frac{1}{4}$
	$4\frac{13}{16}$	5 ft. 11 ins.	... ...	$3\frac{1}{8}$
	$4\frac{5}{8}$	5 ft. $9\frac{1}{2}$ ins.	.. ...	3
	$4\frac{7}{16}$	5 ft. 3 ins.	... ...	$2\frac{7}{8}$
	$4\frac{1}{4}$	5 ft. $0\frac{1}{2}$ in.	... ...	$2\frac{3}{4}$
	$4\frac{1}{16}$	4 ft. $8\frac{1}{2}$ ins.	... ...	$2\frac{5}{8}$
	$3\frac{7}{8}$	4 ft. 5 ins.	... ...	$2\frac{1}{2}$
	$3\frac{11}{16}$	4 ft. 2 ins.	... ...	$2\frac{3}{8}$
Tenor C,	$3\frac{1}{2}$	3 ft. $11\frac{1}{2}$ ins.	... ...	$2\frac{1}{4}$

Diapason Normal Pitch.
Pressure $3\frac{1}{2}$ ins.

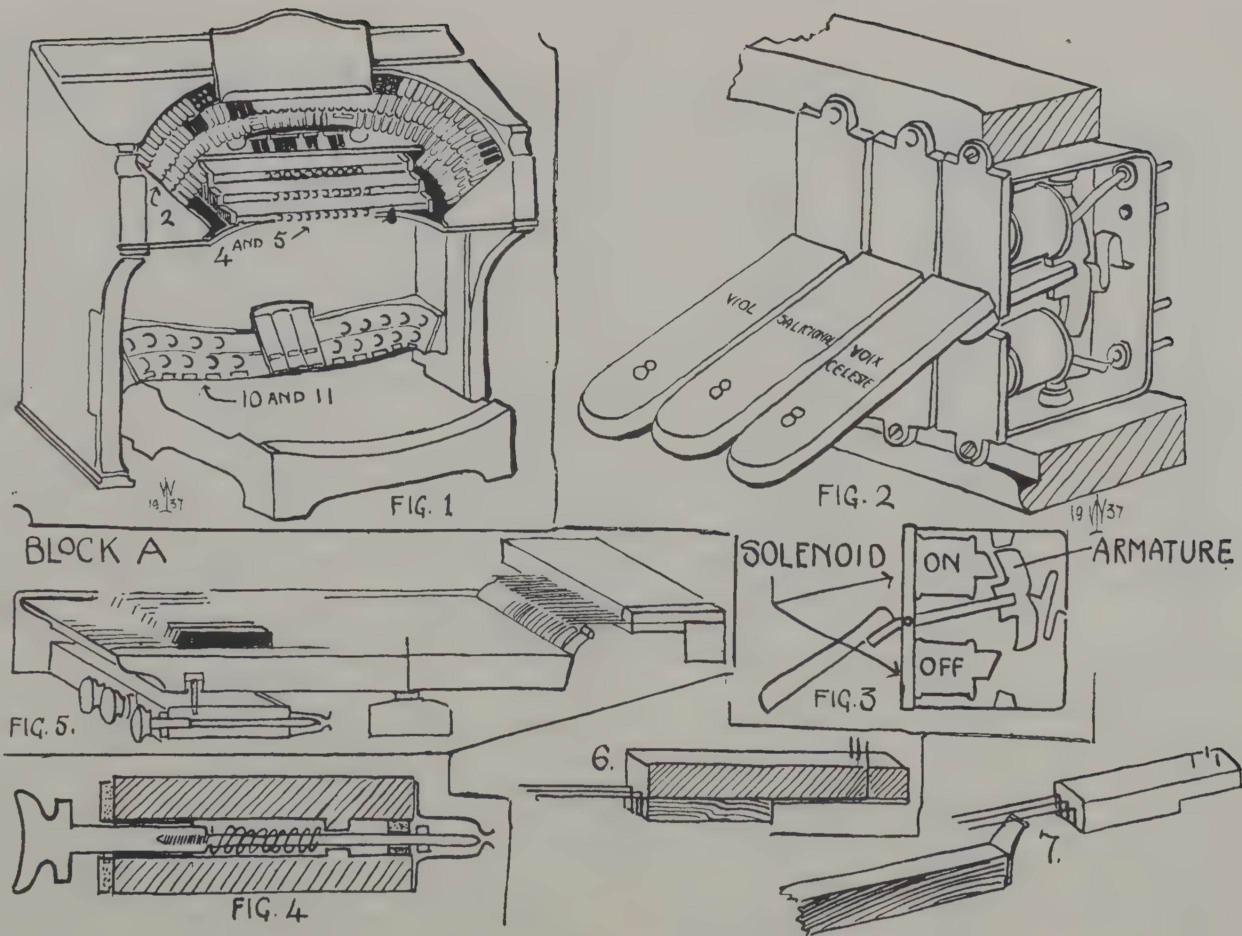
Dulciana lengths, CC = 8 ft., C = 4 ft., graduated approximately as the Open Diapason.

WARNING. If any doubt exists in any matter concerning organ building, it is preferable to err on the side of liberality. Respecting wood pipes, these cannot be lengthened once made. If scales are decreased, or wind pressure increased, or pipes made to speak louder than the examples, more length will be required, especially in the bass.

MODERN ELECTRIC CONTROL AND PNEUMATICS

1. We add these pages to extend the subject to the time of writing from the Hope Jones and other methods illustrated on Plate 36. The historical side of latter-day electric developments receives mention in our remarks under "Time and Progress" in the forefront of this book.

2. The elements of any electric control are, the magnet, armature, the connecting wires, and contacts. Electro-mechanism is, generally, of the simplest possible kind, but this is offset by the amount of repetition required in organ work, and by the modern inclination for automatic controls. These are nearly all, if not in name, couplers in effect. In addition to manual and pedal couplers, fixed, and still more, variable stop combinations, unit chests and extension work are methods of coupling. The nature of the conditions is manifest if one considers, without any *bric a brac* on the console, without couplers, without any borrowing or deriving whatever, and with the aid of pneumatics, one magnet and appurtenances must be used for every manual and pedal key. To have, for instance, an electric bell on one's front door is rather different to having a couple of hundred such in the home. In quite a small two-manual organ there may be three or four hundred pipes, and a thousand pipes would not make a large three-manual. We wonder if enthusiasm for direct electro-mechanics, one pipe, one magnet, outside the trade, ever reflects upon such facts as these? Obviously, the standard of performance must



Block A

OUTLINE OF ANGLO-AMERICAN CONSOLE, FIG. 1, AND ENLARGED DETAIL. STOP-KEYS AND PISTON SOLENOIDS 2 AND 3. PISTONS 4 AND 5. CONTACTS FOR KEYS 6 AND 7. DETAIL OF FOOT PISTONS 10 AND 11 ON BLOCK B

be very high indeed from every component for results from the ensemble.

3. The five pages of illustration to this section include over thirty separate diagrams. These are reproductions of pen sketches by one of the writers, in which a certain amount of freedom is used. They are therefore not accurately to scale, but possibly more illuminating for most readers. We refer to them as Blocks A, B, C, etc., each separate diagram having a number.

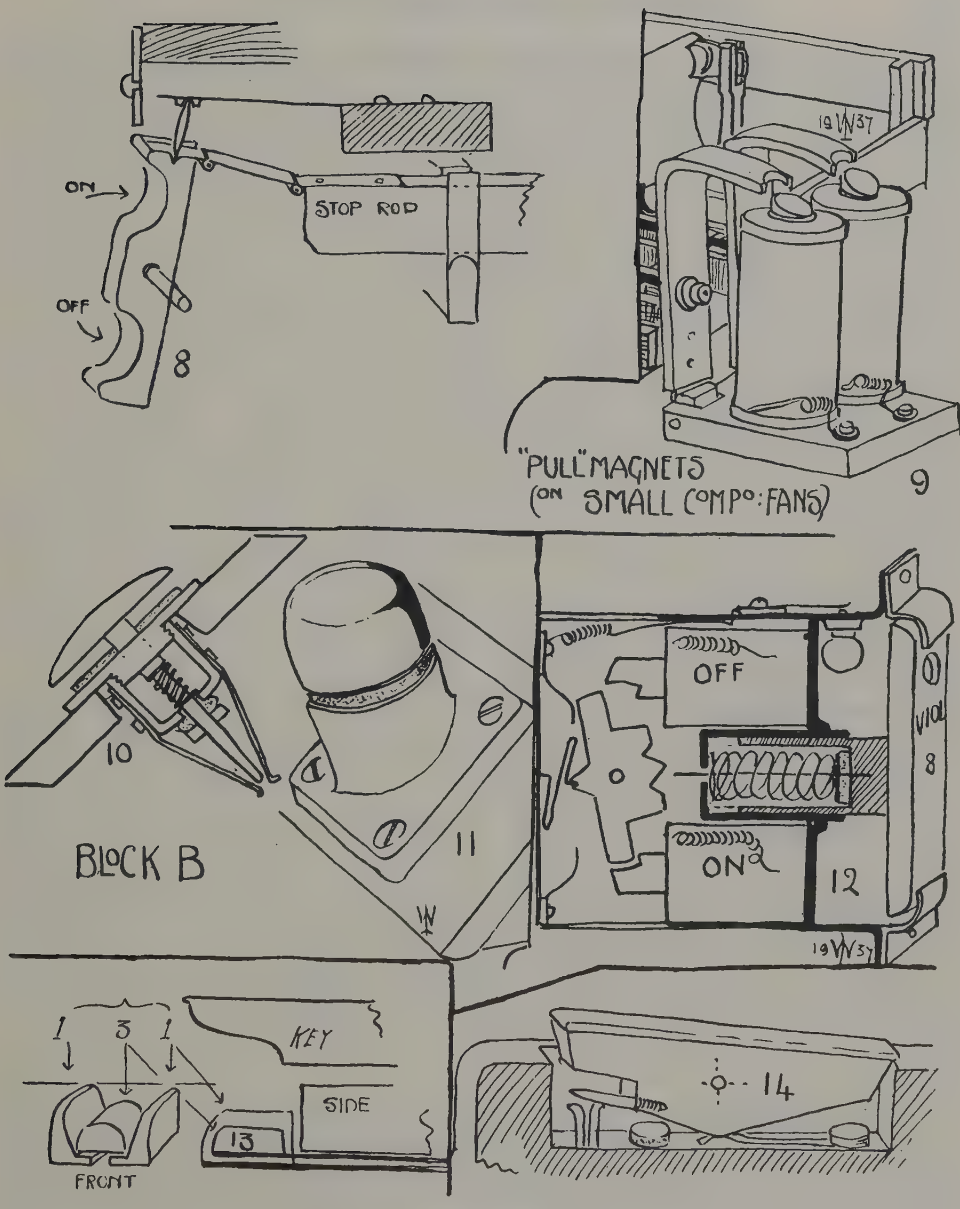
4. Console. The outline of the console, Block A, Fig. 1, presents the Anglo-American Hope Jones type, not, however, always consistent with the illustration. The "lines" are based on the theory of bringing everything within the natural ambit of the limbs of the organist—a further extension of the idea which gave us the concave and radiating pedal-board. The organist is the focal point of the curves. The stop keys are arranged elliptically upon a plane inclined towards the organist. The pedal pistons follow the lines of the pedals. The keys may incline a little. Where two rows of pedal pistons are used, one row may be "stepped" below the level of the other. The swell pedals are of the balanced type, now universal. The stop keys may be coloured systematically red, black, green, violet, etc., and white to distinguish classes, as manual couplers, to pedal couplers, diapason, string-toned stops, flutes and reeds. The idea of having a pilot light in circuit with each stop originated in the gloom of the cinema, where these coloured (or otherwise) brilliants enabled the organist to follow the registration of the stops from the pistons.

5. The console generally has a stop switch, the origin of which was to cut out all the stops on the console on the main return wire to prevent possible wastage of current when the organ was out of use. This found a new use, however, for, when "off" all the stops are "dead," so various changes in registration can be made which do not come into effect until, by one touch, the stop switch is put "on."

6. There are several variations away from the strictly tailor-

made console on scientific anatomical principles, to the straight and angular. Stop-keys do not make a good display unless there are a lot of them. Personally, we prefer to look upon the rocking-tablet kind which preceded them, of which we make mention at the end. One problem of the detached console remains unsolved—or insoluble. It was assumed originally the organist would be able to see over or around it to keep an eye on the choir, but there is very little in this in practice. Maybe it is a question as to whether it is better to arrange the stops scientifically and get a pain in the neck from looking up at the music-desk, which must be above and clear of them, or whether it is, on the whole, more comfortable to keep the desk down and put the stops to bass and treble only. But in any event the desk, if not the top of the console, obstructs one view beyond. No one would wish to under-estimate the value of a good arrangement, but as illustrative in this respect the writer remembers setting out a line of composition pedals many years ago (before foot-pistons were used here) so that they inclined towards the pedal-board. The comment of the musician was he "supposed it would save his bootlaces." We know a young organist who performs brilliantly upon a three-manual tracker organ with square jambs which put the stops out of sight, and we have heard of another who plays the most modern of electric organs who annotates his recital programmes with comments upon the technical difficulties he surmounts, which, however, his new console is designed to ameliorate. Dr. Collinson, one-time organist of St. Mary's Cathedral, and the University, Edinburgh, frequently expressed his admiration for the Hope Jones consoles at these places. St. Mary's was a rebuild, and one of the best examples of H. J.'s work. Dr. Collinson, however, did not extend his admiration by specifying electric control for new organs that came under his direction.

7. The cause of the origin of the rocking-tablet was, of course, the fact that it was designed as a quick make-and-break switch, practically, a tumbler switch, and it does not fit in with angle jambs very



Block B

HOPE-JONES ROCKING STOP-KEY 8. PULL MAGNETS 9. FOOT-PISTONS 10 AND 11. PUSH "ON" AND "OFF" STOP-TABLET 12. HOPE-JONES KEY-TOUCH 13, AND TREMULANT ROCKING-TABLET 14

well, so another way of arranging the stops had to be found. It is an electrical engineer's idea. The stop-key, which followed it, was the same but simplified. We illustrate both. At least one manufacturer in Germany uses the H. J. rocking tablet for pneumatic consoles.

8. Stop-keys. The ones illustrated (A2) may be considered as enlarged detail of the console (1). Upon pressing these down the eccentrically arranged motion "flips" suddenly down under the finger and up at the armature (small diagram 3). To put the stop "off," a touch under the key causes it to spring back. The keys are attached at angles variously from 15 to 30 degrees. Under control of the piston (4 and 5) the stop-key becomes automatic switch-gear. When the thumb-piston (4 and 5) is pressed in, contact is made by the pointed wire passing between the contacts, and assuming the solenoid "on" (3) is in connection the armature is drawn up: as illustrated, the stop is already "on," so if the "off" solenoid (3) is in connection the traction is downward, and the stop-key lifts, being centred on the front of the metal frame. For set combinations of stops the piston works a relay, all the "off" and "on" solenoids being connected as may be required for each piston to the relay. The automatic relay Block C (16) works as the magnet draws up the armature contact-bar, so supplying any wires connected to the contacts. The stop-key described (A2) is a standard component assembled in a metal frame, one for each stop, as illustrated, each component being self-contained. The tablets are screwed on according to stop names required.

9. The diagram 12, Block B, is designed to illustrate the method of bringing stops on or putting them off by a push only, as with a reversible piston. As far as we know, no one uses this particular design. The name tablet is shown vertical, but it could be at an angle, or made round like a piston or stop-knob. It is fixed upon a round tube working in a bushed socket, the coil-spring within keeping the tablet always against the front, shown with side removed.

This is assembled as the stop-key described, the screws for fixing pass through lugs which hold the front on, so the tablet can be removed by drawing the tube out of the socket. A pliable flat steel is shown passing through the coil spring with the free end ready to engage in the V notch on the reversible mechanism, which is shown "on." Upon pressing the tablet it would be tipped the other way, and so would automatically be arranged to reverse again at the next push. A glow lamp in circuit lights up to register "on," so illuminating the semi-opaque tablet from behind, or showing through the perforation.

10. The piston action operates the solenoids, as previously described, the only means of registration being the pilot light. The solenoid "off," when in circuit, attracts the reversible mechanism, which is, of course, free to tip either way.

11. FOOT-PISTONS. Reference to Block B (Figs. 10 and 11) shows two designs for "foot-pistons" which have now replaced the composition pedal. Both are self-contained components, the description therefore applies equally. The general arrangement of these is indicated on Block A 1. The domed or mushroom top is pressed down by the foot, so making contact as shown, Block B 10. Any remarks in general applying to pistons, key-touches and composition pedals previously made herein apply to foot-pistons, which are simply to the feet what the former are to the hands. The difference between piston and key-touch is, the former are set on the key-slip and are pressed by the thumb (generally) from the manual above them, whilst key-touches are pressed down by the fingers on the manual they control. T. C. Lewis and Hope Jones used key-touches, the former an ivory turned press-button as previously illustrated herein, the latter as shown here, Block B 13. The point of interest with the latter is that three distinct movements are grouped as one. Thus, the two controls marked 1 (Block B 13) are independent, each, we will say, adding stops. The middle one, 3, is arranged to engage upon the flanges of the others, so all three move when the middle one is touched. They may therefore be used for building up

in three movements, or, as one only. Assuming three of these triplex touches, there would be nine independent movements. As shown (B 13, side), these metal levers passed under the key rail, making contact at the back of the rail. In passing, we note the Hope Jones rocking tablets, as for stop control (8) the other design for, usually, tremulants, set in the key-frame as shown, 14. The idea of the hollows worked in the ivory was that adjacent stops might be moved by *glissando*.

12. CONTACTS. Returning now to Block A, a standard system of contacts is illustrated (5, 6, 7). Enlarged detail of a single component is sketched, 6 and 7. The fine wire contacts are set in machine sawcuts made in pine blocks, one end of the wire projecting for contact, the other bent at a right angle and forced through the wood to make a terminal for soldering the connection. A metal clip fixed to the end of the key with a silver wire soldered to its edge lifts as the key is depressed and touches the "brush" of contacts. The width of the block is decided by the key-scale, so for the manuals would be something less than half-an-inch. The number of contacts might be one for the main, one for each coupler on or to the manual, one for the "neutral"—so called for the negative side of the power—variously from three to eight in the one component. Hence the scale is much finer than formerly, when the arrangement was from back to front and secondary contact mechanism was used. The blocks are glued or screwed between, on a rail (5). Larger blocks and contact clips are used for the pedals.

13. MANUAL AND PEDAL CONTROL. The object here is to open pallets or valves to supply pipes. With the slide soundboard auxiliary pneumatics are used, but with the pneumatic soundboard it is possible to omit these. The earliest experiments were of this kind, the direct electro-mechanical traction of the pallet being aimed at. William Wilkinson, of Kendal, attempted to apply the electro-magnet invented by William Sturgeon directly after the latter discovered the electric telegraph, 1826. Had they succeeded we might long

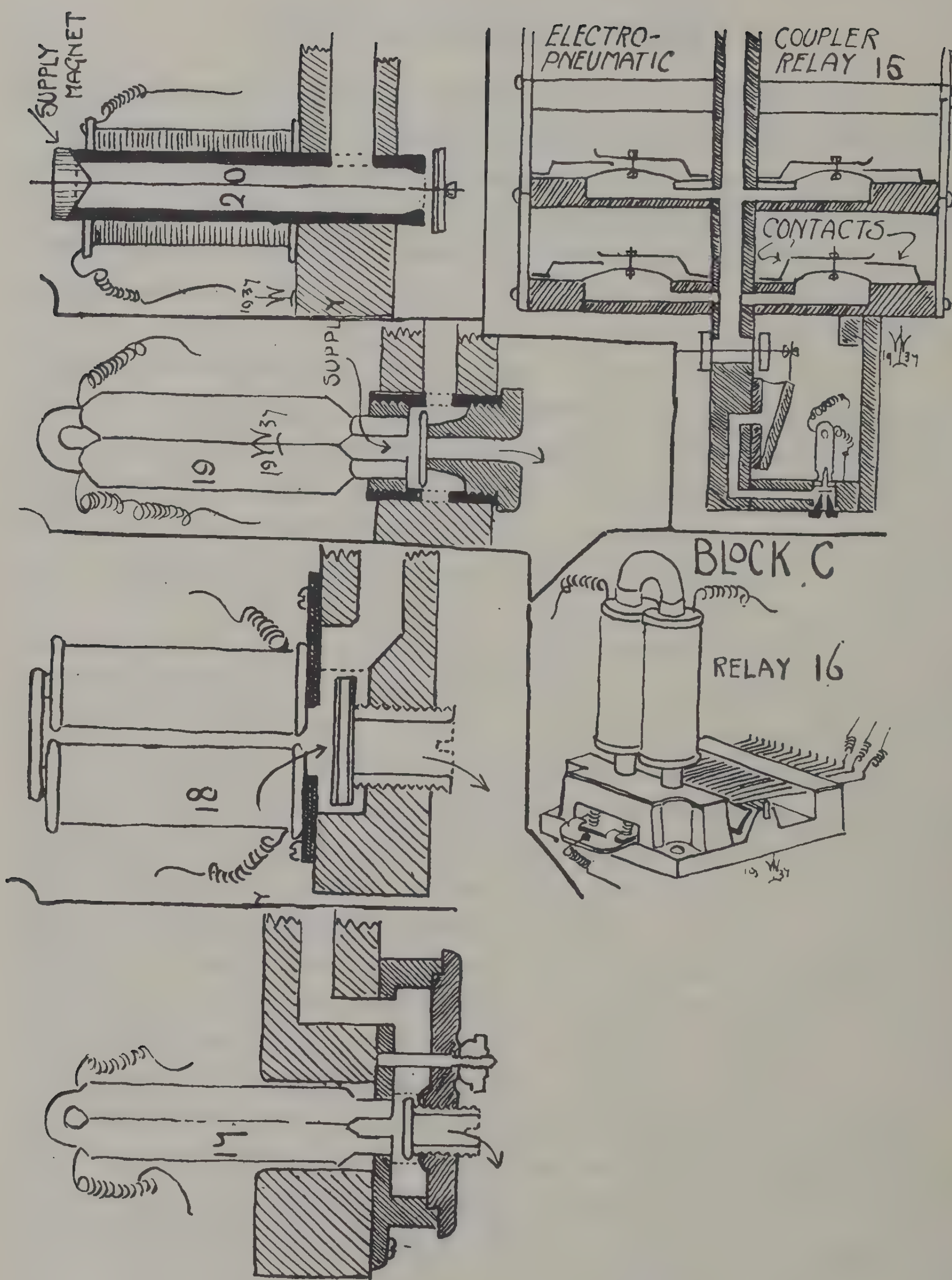
have become accustomed to connecting the company's main up to the organ, subject to certain stipulations, but this method has such objections that the safest course was to abolish the soundboard, which took time and progress of pneumatic action to accomplish. As nearly all electro-mechanical appliances are based upon the electro-magnet, what now do we not owe to the pioneer, Sturgeon, the humble mechanic?

14. The valves used in pneumatic actions cover holes variously from quarter of an inch diameter up to three-quarters of an inch, or rather more, as illustrated previously. Similarly, with the pneumatic soundboard, such as the Roosevelt, already explained, the valve holes for the pipes have the same range for average requirements down to the 8 ft. Open Diapason. This, it is true, is hardly adequate in the bass for the stop named.

15. Standard components with this range can be obtained, hence electric control depends upon the extent to which auxiliary pneumatics are used.

16. There remain two types, the Hope Jones floating armature, which was an improvement on Schmoele and Mols patent, originally combined T. C. Lewis's pneumatics, and subsequently with a modified design. Variations on this are suited to exhaust actions (see Block C, 17, 18, 19). The other type is suited to supply or exhaust according to its design, being in the line of descent from Dr. Peschard's patent (1864) and Barker's (1868), shaped into a self-contained component (resembling closely the design illustrated here) by Roosevelt. This evolution of design may be traced by a comparison of Plate 36 with the illustration here added. The indefinable nature of a "patent" is well illustrated by a comparison of Peschard's and Barker's designs, the difference being more to do with the associated pneumatics. Presumably one may obtain a patent for electric action by varying the pneumatics.

17. The descriptions of the primary action magnets are: Block C 17. A hole is bored in the wood close to the groove to be controlled

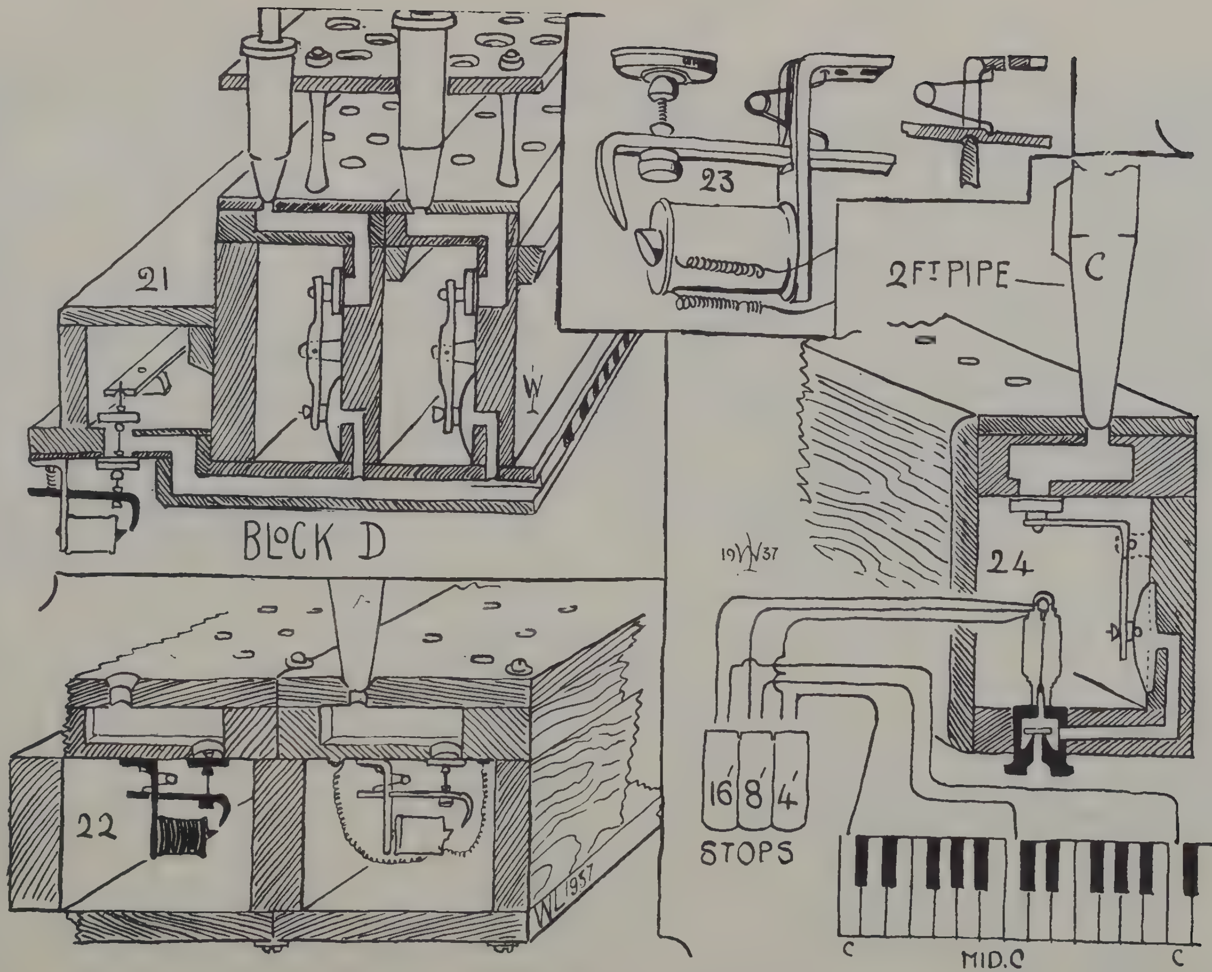


Block C

ELECTRO-PNEUMATIC COUPLING RELAY, 15. ELECTRO-MECHANICAL RELAY FOR COUPLING OR PISTONS, 16. PRIMARY ELECTRO-PNEUMATIC MAGNET, 17. DITTO, 19 AND 20. SECONDARY ELECTRO-MAGNET, 18

to admit the magnet being enclosed within the action box. It is mounted on a die-pressed bakelite fitting screwed in position from the outside. A regulating "thimble" is shown upon which the disc valve armature normally rests. When energised, the magnet lifts the valve, so closing the supply between the magnet arms and opening the exhaust down through the thimble valve seat. The cover of the fitting is removable by unscrewing the milled nut. The working of number 19 is the same. This component is die-moulded lead, in three parts: (1) the tapered valve seat unscrews from (2) the cylinder, and the magnet is fixed into the (3) block in which is the supply port, which likewise screws into the cylinder. The component is fixed by boring a hole in the wood in connection with the groove to be exhausted, and is pressed in tight. Number 20 differs in being designed for supply action, and there being a lack of such, it would appear, the draughtsman set out the one illustrated. The core of the solenoid is hollow, the component being mounted by boring a hole in the wood and pressing it in. An ordinary pneumatic valve on a tapped wire is used, the upper one being conical. The top might be left without being countersunk, and a register could be pressed into the lower end. It should be plated. Very fine supply or exhaust ports should be avoided, as although such economise the power of the coil necessary, they silt up. Block D 21, shows a tilting magnet and valve arranged to exhaust the groove. Such a pattern may be made suitable for supply action by extending the pivoted armature more to the rear and drilling for the tapped wire of an ordinary double pneumatic valve. The characteristic of this design increases the power of the coil by reason of the shape and arrangement of the armature, so made that it describes an arc about the point of the solenoid, so the gap remains constant. The power of magnetic attraction is as the inverse square of the distance, hence it is a great advantage to keep the gap as small as possible.

18. A secondary action magnet, which therefore is larger and more powerful than the ones described, as it replaces secondary pneumatics, leaving the main motor, is shown Block C 18. This is mounted



Block D

ELECTRO-PNEUMATIC WIND-CHEST 21. ELECTRO-MECHANICAL WIND-CHEST 22. ENLARGED DETAIL OF ELECTRO-MECHANICAL PALLET 23. UNIT CHEST WITH COMPOUND ELECTRO-MAGNET CONTROL 24

inside the wind chest, a round hole being bored in the bottomboard to take the armature disc valve, and a smaller one into which the valve seat is screwed. Block D 21 shows a chest magnet of the other type.

19A For stop machines drawing slides, Hope Jones used two primary magnets, one "on," one "off." The circuit was complicated, however. With pneumatic soundboards and ventil control one magnet "on" simplifies the work. The pneumatic pallet (invented by Bryceson) is now preferred for ventils. It is a bellows motor which opens square with the pallet glued on top, as shown Plate 34 previously in connection with a composition action. (The motor 4 shown there, however, is hinged. Bryceson's pallet was hinged.) As the ventil is required deep enough to take a connecting trunk, the motors may be raised on a rail. Another method is to introduce a cardboard tube against the lower end of which the pallet shuts.

20. Direct Chest Magnet. "Direct" electro-mechanical action, so called, is illustrated, Block D 22. The sketch shows a section through two compartments of the chest. The soundboard (chest) is similar to the Roosevelt, having one compartment lengthways for each separate stop. There is therefore a disc valve for every pipe, as shown, under control of a solenoid. Enlarged detail is given, 23. The spring retains the valve closed. The object of this is to favour borrowing, for as each pipe is independent, wiring up a suitable circuit enables a bass or stops to be loaned, although in that case stop control is not by ventil, but by electric relay. If not for borrowing, it is difficult to see the utility of this method, except it would sell plenty of manufacturer's magnets, as it would seem to be more expensive than the usual system shown by the sketch above, 21.

21. This (21) represents the modern American wind chest now generally favoured, excepting the electric control may not be of the type shown. Each compartment is controlled by a ventil. Groove boards screw up on the underside, all the "puffs" for each note being connected to the groove. A pivoted "jack" is connected to the puff, the valve being on the other end, so, when the main groove is ex-

hausted by the electric control from the key, all the valves open as the puffs exhaust into the groove. When a stop is put "off" a ventil shuts, the supply to the compartment is cut off and a small exhaust opened, upon which there is no wind to work the puffs or to supply the pipes. The valves are shown "off." This is simply the Roosevelt chest with puffs instead of motors to simplify it.

22. The Unit. The unit is the ultimate development of the pneumatic soundboard, the original intention of which was to abolish the troublesome slide. As a matter of fact, the slide soundboard developed from the pipes and has a musical basis, but it is not adapted to the automatic action. A ventil has mechanical advantages over the slide, as it is much simpler to control. As pneumatics were not adaptable to the slide soundboard, builders on the Continent and in America abolished it, and their soundboards since then have inevitably taken that line of evolution to suit the action. Weigle influenced German builders, Roosevelt and Hope Jones, American. T. C. Lewis experimented with an excellent type of pneumatic soundboard, but it got no further than the store room, where he put it in the end. Other English builders used pneumatic soundboards for a time, but discarded them. Now we believe they are generally favoured. A pneumatic soundboard is not necessarily inferior to the old method. Both have characteristic excellences and objects. No system is perfect which we have investigated, speaking from the exacting standpoint of the trade. The test of an organ is, of course, a musical composition, preferably one composed for the organ. Strictly, anything other than this is not relevant at all. The pipes are the standard of organ building, the Diapason Standard, which is the basis of organ music, as it is the basis of the musical scale of the organ.

23. The automatic action made the relation between pipe and key so flexible that finally it becomes fluid. The unit chest is an example. What are known variously as deriving, extension, borrowing, and duplicating, find their exemplar in the unit chest. There are various methods of connecting up the unit, the one illustrated, Block

D 24, is the latter-day equivalent of the tubular-pneumatic system represented on Plate 47, and has similar mechanical implications in respect of electric coupling. Any system of coupling will accomplish unit control, but some are preferable to others for their simplicity.

24. Block D 24, is a sketch diagram of a unit chest, two octaves of keys, and three stop keys. The section shows the 2 ft. C pipe standing upon the chest with the pipe valve connected via a metal square working in a clip, which springs closed upon the points of the centre pin. The lower end of the square is connected to a purse which, when the magnet is energised by holding a C key, collapses by exhaust through the port opened when the disc armature lifts. There is, of course, wind in the chest.

25. An alternative arrangement dispenses with the square, the purse being arranged on the bottom directly under the pipe, the valve being on the end of a tapped wire registered by a flat spring projecting from the back.

26. The characterisic of this method is the compound-wound magnet. The one illustrated has three separate coils, the first wound on the magnet, the second insulated on paper from the first, the third similarly insulated from the second. The diagram of connections is modified to explain how the 2 ft. pipe is coupled to the key at unison, or 8 ft. pitch (2 ft. pipe on Mid C key), also at sub-octave or 16 ft. pitch (2 ft. pipe on C above middle), and also at octave pitch (2 ft. pipe on Ten. C).

27. Starting from middle C we trace the connection to the stop-key marked 8 ft., which we can assume to be any stop we like—say, Open Diapason. Assuming the stop-key is on, the connection goes through to the magnet on one winding, so the pipe sounds on the middle C key, which gives the unison pitch, the standard of the keyboard. Other pitches, as sub or octave, and for that matter, twelfth, fifteenth, nineteenth, twenty-second, which are super-unison, count ascending on the white keys, from the standard—i.e., middle C. Now a key is not a standard, as one octave is a plain repetition of another.

Pipes are the standard of organ-building—the 2 ft. open pipe on the middle C key defines it, so there is no repetition whatever, as every pipe has a different length and a diameter proportioned thereto in fixed relation.

28. Similarly, we may trace the connection from C below middle through the 4 ft. stop-key, which we could call Octave, 4 ft. And again from the C key above middle through the 16 ft. stop-key which we would call Double Open Diapason.

29. So, singly or collectively, the three C keys on the example would sound the same pipe, but as pitch is relative to key, it becomes in turn 8 ft., 16 ft. and 4 ft. *pitch* or *tone*, by thinking in terms of keys and not pipes. In other words, music and organ building are in these days so far specialised, that the musician commonly thinks in the abstract, but you cannot have an abstract musical instrument. The system of music in the organ is tangible substance, with length, diameter and weight, or there is no music, as there would be no Chopin without piano strings.

30. Obviously, one pipe will not make a unit, but if every pipe that can be is transferred above or below, or is to unison, as indicated, then one extended rank can be used at three different pitches in relation to the keys. Add to an Oboe 8 ft. twelve pipes to extend the bass down, then it can be used as a 16 ft. or Double Oboe also, on the manual and borrowed by the pedals. Similarly, an 8 ft. Clarabella might be used as a Bourdon 16 ft., and a Flute 4 ft. Again, a Salicional 8 ft., as a soft Double 16 ft., and Gemshorn 4 ft. Practically, the unit comes down to not more than three, but a number of intermanual or pedal "duplications" may also be used. But one thing is impossible—you cannot play one pipe more than once at a time, hence the unit is at its best played solo.

31. Coupling. An American system of electro-pneumatic coupling is illustrated, Block C 15. This is a relay from the console, the section showing four pneumatic puffs each in a separate compartment, connected to a vertical groove in common to each note. The

puffs are held up by spring contacts. The couplers are put "on" from the stops working ventils (not shown) which supply the compartments with wind. When a note is held, the magnet is energised, the motor and double valve reverse, and the puffs exhaust into the groove —or such as work by reason of their compartments being supplied with wind. When a coupler stop is "off" the compartment is exhausted, hence the puffs do not work. Contact is made by a puff drawing down the spring contact on to the stationary one. Four compartments are shown, representing four couplers, with glass faceboards. More couplers means adding compartments vertically.

32. An electro-mechanical coupling switch may be arranged on the lines of 16, Block C, with individual contacts. The one illustrated supplies a number of contacts in common. On Block B 9 large magnets for pulling on switch gear for coupling are illustrated (to another purpose). Resistance coils are used with large magnets to minimise sparking. As with tubular coupling, the essentials are, a means of bringing couplers "on" and releasing, combined with an arrangement that avoids "running back," i.e., Swell to Great, for instance, must be prevented from acting the reverse way, and becoming also Great to Swell.

33. Swell Pedal. The Hope Jones method of electro-pneumatic swell shutter control is described previously herein. It is operated by opening each venetian shutter separately, there being a contact and pneumatic control for each shutter. A simpler method of later date, and doubtless a better one, is shown, Block E 29. This arrangement connects to the mechanical action of the shutters, which opens them all together as it is moved from closed to open over a distance of two and a half to three inches.

34. As, theoretically, there is no degree between closed and partially open, and practically the first slight movement of the shutters open has the most marked effect, that stage of motion of the automatic control illustrated must be least in extent.

35. The arrangement consists of three bellows one upon the

other, shown all distended to close the swell. The section discloses the action necessary for one, there being two repeats in the action box. As illustrated, the magnet is "on," the pneumatics are supplying the top bellows via the groove and way up through the other bellows. The detail, D, shows a way of isolating the wind, by passing it through small motors, which extend and collapse with the bellows, being glued top and bottom.

36. The swell pedal movement at the console is divided into three contacts, controlling the pneumatics. As the pedal is moved one bellows after the other distends, with the reverse. If the swell is moved right over quickly, all distend together. Hence the pneumatics not only graduate the motion between contacts, but are to some extent sensitive.

37. In passing, a point of some consequence detains us. With the automatic swell action it is preferable for a spring to keep the shutters open, hence the pneumatics close the shutters against the spring. The reason is, that when the organ wind is shut off, the shutters open, irrespective of the pedal, so changes in temperature are not excluded from the box. Although we speak of a swell or crescendo, a box is in fact the opposite. It is nothing but a diminuendo box, as the positive effect of shutting pipes in is to prevent the sound coming out. This was its original purpose until shutters were added. The crescendo or increase of sound is as the effectiveness of the extent the box blankets the sound-waves, and only exists negatively, by contrast. This is not the only respect in which we commonly overlook values. The "stop," for instance, was originally intended to prevent pipes sounding, which is probably its real purpose now, unless we regard the organ as normally dumb! In any event, a swell is probably longer open than closed, so it seems advisable to keep the "off" position of the action for the open swell. The balanced type of pedal is illustrated in connection with the matter following. Another type of automatic swell may be arranged by enclosing the

bellows, so the wind acts both "off" and "on," but this is, of course, more complicated.

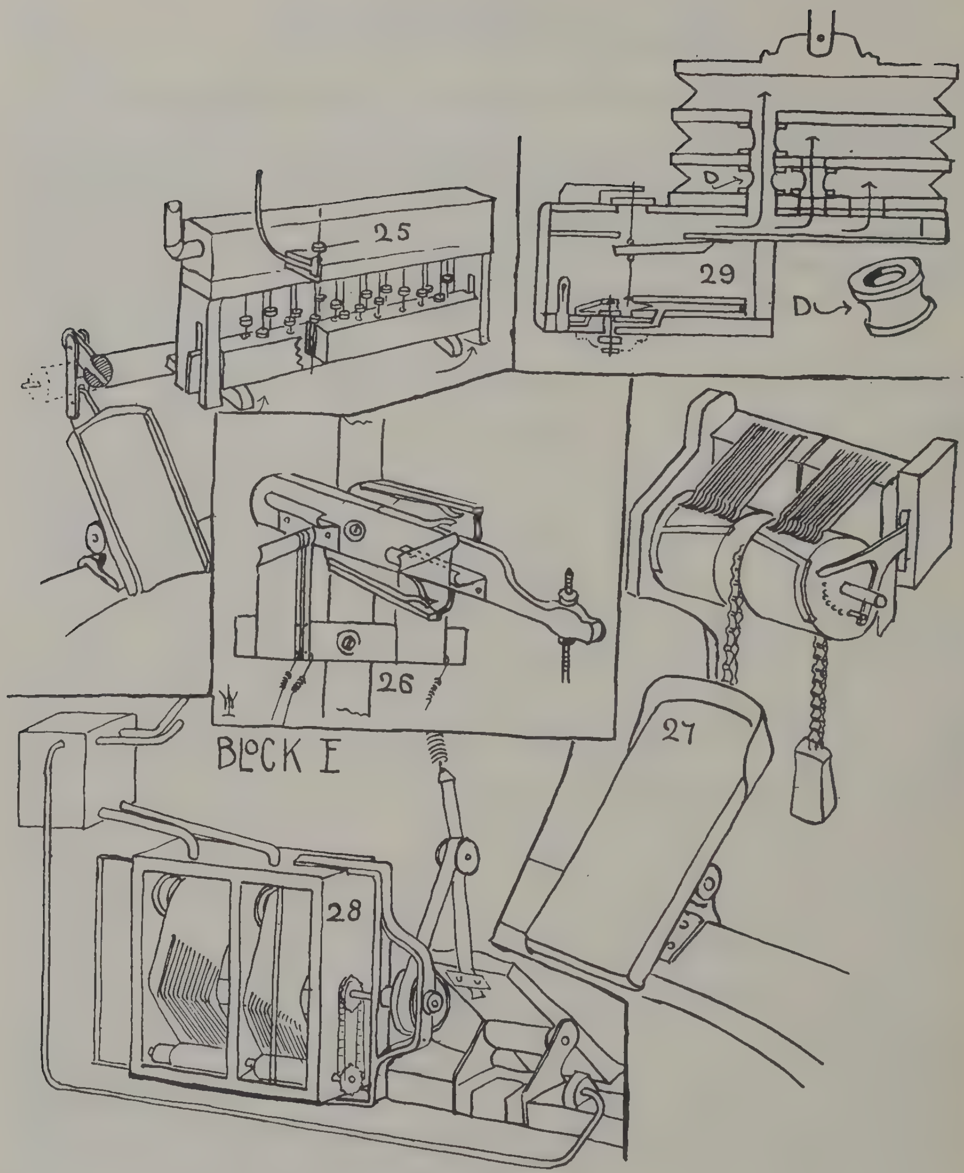
38. The automatic swell cannot at best do more than the direct connection, which is theoretically perfect, and can now be made as light and easy to move as the automatic.

39. SFORZANDO PEDAL. Although this receives mention earlier in these pages, we did not give an example. Since writing, its popularity has increased. This, or as it is sometimes termed, crescendo-decrescendo pedal, brings on stops one by one to full, with the reverse.

40. It was the original form of composition action which came into existence with the automatic organ introduced early in the eighteenth century, when such were largely used in country churches, following the black-out of English music and art that followed the Renaissance and the violent change in the life of the nation that began with industrialism. These things disappeared with the religious revival, but the composition action stayed on and developed. The original form was a cylinder which revolved and "played the stops" much as it played the key action.

41. In Germany the organist does not seem to mind much whether the pistons register on the stops (or possibly, the organ builder). This pedal is easily arranged under those conditions, and is a feature of ventil controlled pneumatic soundboards. It is the movement of the stops in tubular work that elaborates the piston action, otherwise it is little more than running the necessary tubes Whilst no one doubts the superiority of the English method of registration by moving the stops, in the case of the crescendo-decrescendo balanced type of pedal, there is something to be said in favour of the Continental custom In any case, this starts by adding to any stops being used at the moment, and if on the return stops are moved in, then the combination in use is wiped out and nothing remains.

42. Figure 25, Block E, illustrates a tubular pneumatic crescendo on the ventils connected to a balanced pedal. We can com-



Block E

TUBULAR PNEUMATIC CRESCENDO-DECRESCENDO STOP CONTROL PEDAL, 25. DITTO, 28. ELECTRO-MECHANICAL DITTO, 26 AND 27. AUTOMATIC ELECTRO-PNEUMATIC SWELL-SHUTTER CONTROL, 29

mend the example as a tried and dependable method. The pedal should be provided with a means of regulating resistance by friction. The action consists of a trundle connected to the pedal which lifts parallel a beam registered both ends in slots in the fixing. A small valve on a tapped wire is provided for each stop. The valve covers a hole in the box (over the beam) and the stem passes down through the beam. Every valve has a regulating button by which the sequence of the stops coming on is arranged. As the beam rises, one valve after another is carried up, so supplying the stop action or ventil tubes. The wires register through the top of the box, and should have a coil spring or a weight on each to return them as the pedal is reversed.

43. A further elaboration divides the wind box into independent compartments, one for each manual, each being supplied with wind from a stop on the console, when drawn. On drawing, say, Great Crescendo, that department only is affected, similarly, Swell Crescendo would add, or be independent. One organist we knew had his Choir Organ specification arranged by selecting suitable stops to conform to a gradual increase of volume by addition, in preference to enclosing. This system might be applied instead of swell boxes, but it would have musical consequences, but not more so than the unit, the unison tone quality of which decides the sub and octave stops from it.

44. Figure 28 (Block E) illustrates another method of making a tubular crescendo pedal. The machine is a box divided by a partition with a sliding glass front (shown partly open). Inside are shown two "blinds" of linen music-roll, suitably perforated to bring on the required stops which are tubed up to the tracker bar from the back. The two rolls are wound on to the lower spool by the chain drive as the pedal is moved, the upper spool having a coil spring like a spring-blind to rewind the rolls automatically as the pedal is reversed. Connection to the pedal is a length of webbing wound round the driving wheel and carried up over a pulley. The machine may therefore be connected further away than convenience of illustration permits.

Wind is supplied through a small ventil box and both compartments charged automatically at the first touch on the pedal. Two stops on the console—Great Crescendo Off, Swell ditto, or as may be, cut out either compartment if drawn, by working the appropriate ventil. There is, of course, no necessity to divide the box if these are not wanted.

45. An electric control is illustrated, 26, Block E. The extended arm connects to the balanced pedal, being centred on the upright. As shown the arm is nearly down. When moved, the contact plates brush over the groups of contacts, one plate being cut out as the pedal reverses either way by the main contacts in the tray. The latter has a slight independent travel and needs a small counterbalance weight (like a "tell-tale" wind indicator) to prevent it dropping. This provides for one magnet "on" and another "off" for each stop. If one sustaining magnet only is used for each stop, then the arm may be arranged to keep in contact by lengthening the rear group to the angle of the contact plate above them, on the example. Two groups are shown mainly with the idea of furthering the suggestion of independent control on two manuals, the electric equivalent of the remarks under this head with reference to the tubular crescendo pedal.

46. Figure 27 illustrates an electric control with a cylinder which gives a part revolution under traction of a chain and wheel connected to the balanced pedal. The weight is a counterpoise. The arrangement is for one magnet "on" for each stop and one "off" as one set of contacts is lifted off mechanically as the other is put on by a roller with cams in opposite directions. If arranged to sustain one magnet at a time, then only one portion of the cylinder is necessary with a wider contact plate, or the two may be used by setting one plate below the other to engage sequentially, and the other mechanism may be omitted.

47. Apart from admitted improvements in design, electric work reveals a tendency to early methods, the reason being it is not now

necessary to conserve the current. Powerful magnets were found to exhaust the old batteries and accumulators, but now the current generator may be a small dynamo giving a direct supply worked off the electric blower. With wind pressure from 4 to 8 ins., current would be about 6 to 10 volts: from 8 to 16 ins. pressure, 10 to 15 volts.

48. Pneumatics. The systems of pneumatics in these pages are modern without modification. When originally published some were in advance of their time, in not being generally known. A rearrangement of motors and valves does not necessarily imply anything new, as such is within the customary routine. The simplest possible way of arranging two motors is to place one behind the other on a flat board, with a joint to permit boring. The simplest system is the exhaust, the next the supply "on" without exhaust other than a perforation at the motor.

49. We have evidence that one noted German manufacturer at least has made good use of this book, and we congratulate him upon adapting the exhaust system shown herein to supply, the latter being favoured on the Continent. Originally, the exhaust system was invented by the late Edward Norman, whose firm spent a fortune on perfecting it. We illustrate a simpler method than the original. Henry Willis developed the older supply system, and it would seem Weigle originated the modification. America profited at the expense of English builders, who paid for being pioneers, both in tubular and electric work.

50. The science of the subject is given herein, the rest remains a matter of adaption to production and particular requirements. In this respect, as noted previously, the pneumatic "puff" is more used than the motor bellows, where possible. Simplification is the order of the day, and a very good one. No one would wish to do more than is exactly enough to attain results, as the least complicated mechanism is the best—other things equal. That is, of course, the point, sometimes debatable.

51. The method of using the exhaust system for supply is to

enclose the jacks at the keys in a box, so they become pallets with the pull passing outside. Otherwise details, including coupling, are the same, excepting one tube for coupling of the pair should be in the middle of the membrane—the one going to the key—and it would be better perhaps if the other were sunk in a groove made by boring with a specially shaped bit.

52. The application of electric control begins by wiping out the primary motor by the magnet or solenoid. The exhaust system appears to be preferred, but in the absence of tubular couplers names matter little. As the intention is to adapt the electric component in the simplest way, this does not necessarily imply that an entirely new kind of action results with every method of doing this. With pneumatic soundboards there is not much latitude for variation. Block D illustrates three applications of electric control to pneumatic soundboards.

53. For the benefit of the organist student the following applications of electric control may be made to illustrations herein: Plate 2, Roosevelt Chest, magnet 18, Block C, will exchange for tube operated motor shown: Plate 5, Fig. 1, magnets 17-19, Block C, will exchange likewise: the type of ventil, Plate 12, by exchanging primary motors for magnet 18: auxiliary Plate 13 by boring groove for motor B into bottomboard in communication with magnet 17 or 19, Block C: composition action, Plate 31, magnet 17 or 19. With free armature valves (17, 18, 19, 20, Block C) as these fall by their own weight, the "off" position must coincide with this, otherwise, if simply allowed to blow upwards by the wind pressure, they will all fall to the "on" position when the organ wind is put off, and so cause a din as they blow up when the wind is put on first. This was a mistake of early Hope Jones work, and might have invalidated his patent had anyone taken the matter up as an improvement by turning the action the other way up! For this reason other pneumatic actions herein would need to be inverted for electric control by re-arrangement of the motors.

ORGAN BLOWING, HISTORICALLY AND SCIENTIFICALLY CONSIDERED

1. It might appear there is little inspiration in the subject of this chapter—the organ bellows—although it must contain the very soul of whatever music there may be in the pipes! A tuned scale of pipes depends for its existence upon a constant and even wind pressure, hence the beginning of the organ was contemporaneous with a wind supply which fulfilled these conditions. To do so it must consist of two parts: (1) one to collect and force air into (2) the bellows or reservoir, which conserves and distributes it through the wind trunks.

2. The historian follows the tradition that not only is a scientifically constructed bellows comparatively modern, but that the reservoir was absent from ancient organs, excepting the hydraulus. As, however, a very slight variation in pressure makes it impossible to tune with accuracy, some of the ancient illustrations of organs imply the existence concealed within of some form of reservoir, although the "feeder" alone is visible? Even the bagpipes has a bellows—held under the arm—the feeders being the lungs of the instrumentalist. The historian generally uses one term only, bellows. There are three commonly used, the (a) bellows, or (b) reservoir, and (c) feeders.

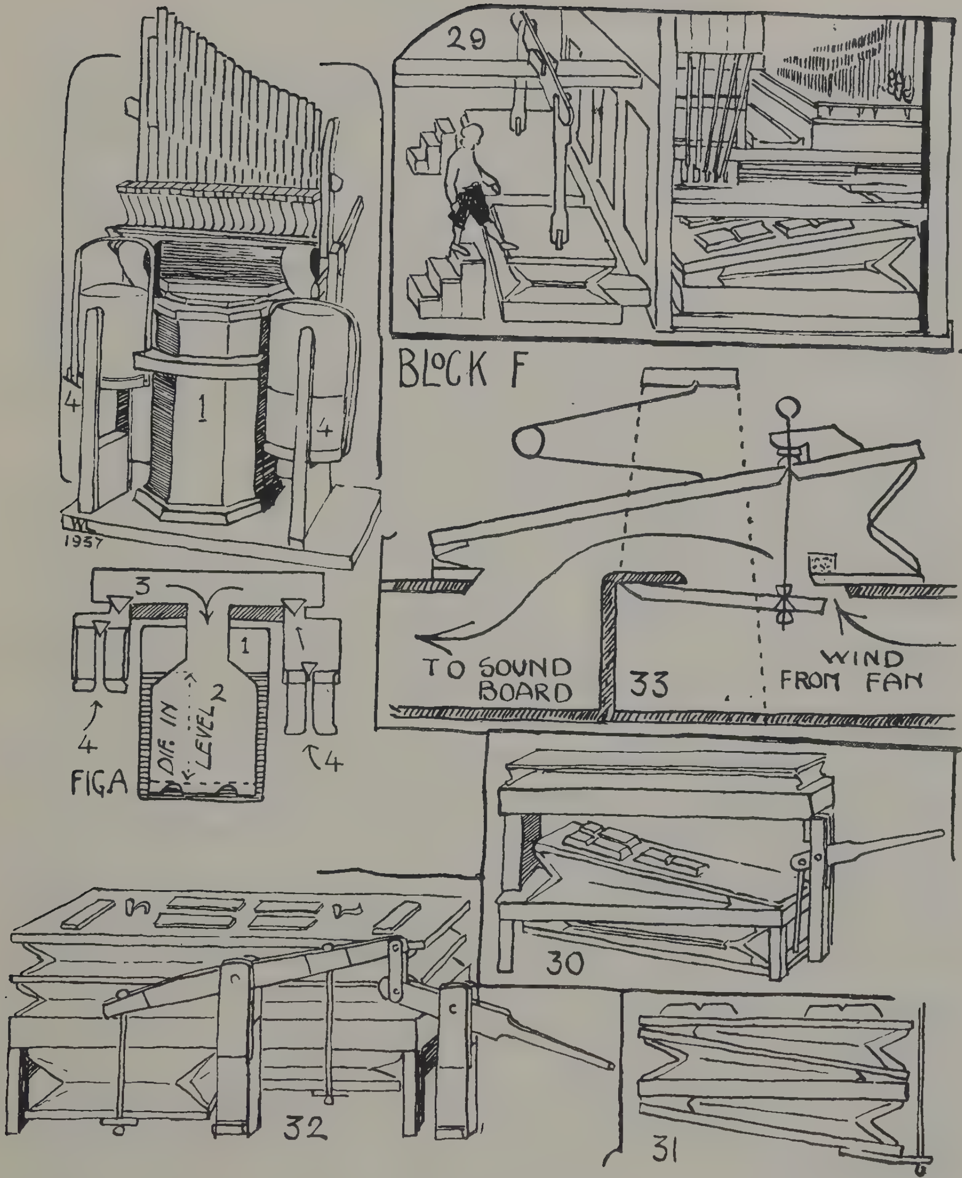
3. The reservoir, obviously, stores a volume of wind, so also does the bellows. The last term usually indicates the "main," into which the wind is compressed first, the reservoir is supplied from the

bellows. The feeders are a special kind of bellows designed to collect and compress the air. By "wind" the organ builder means air under pressure. An essential part of any system is either weights or springs to maintain the wind pressure constant.

4. We propose to recapitulate the history of the subject irrespective of orthodox history, guided by observation of old organs and old methods which survived, aided by trade experience. The evolution of this department is representative of the course followed by the remainder of the organ. It begins with a simple primitive form, becomes complex, and finally returns to a simple form again, if one takes the extreme of latter-day methods in any case.

5. The blacksmith's bellows appears to have been the origin of the most primitive method of blowing, as the forge fan was of the latest. In Egyptian mural decoration smiths are shown with a small bellows under each foot, with strings to pull them open after pressing them flat. This implies valves in the bellows. From most ancient times a similar method was used for blowing organs. Feeders were placed upon the ground externally to the organ, and the blowers stood upon them. It would then be necessary either to lift them open or arrange levers to do so, or springs. This method of the treadmill was preferred on the Continent long after it was discarded here. The hand lever was used more in England—a survival from the pump of the hydraulus. A few years ago a small army of blowers was pensioned off at the Cathedral of Notre Dame, Paris, some being women, where the treadmill survived until the change over to electric power. This ancient method is sketched on Block F, 29, not with versimilitude to the reference. St. Paul's organ, London, was blown by treadmill in Stainer's time. It is assumed, from ancient illustrations, that the "feeder" (or plural) was also the reservoir, and the blower who stood upon it combined the office with that of the weights of much later date. We could believe this if a model of the arrangement could be made to demonstrate it.

6. The method of blowing used with the hydraulus survived,



Block F

ANCIENT "BELLOWS TREADER," 29. HYDRAULUS, FIG. A. DIAGONAL BELLOWS AND FEEDER, 30. DOUBLE-RISE DIAGONAL BELLOWS AND FEEDER, 31. DOUBLE-RISE BELLOWS WITH HORIZONTAL RIBS AND RISING FRAME, 32. AUTOMATIC WIND REGULATOR USED WITH ROTARY-FAN BLOWER, 33

with modifications, to the tenth century of our era. The system of storing and maintaining an even pressure by the hydraulus is illustrated on Block F, diagram A. The metal cistern, 1, partially filled with water, the amount of which would need to be carefully maintained, encloses an inverted funnel, 2, which terminates in the bottom of the soundboard, 3. The two copper air-pumps, with valves and levers, 4, force air into the funnel, 2. So the water within the funnel is forced out, rising to a corresponding extent in the cistern. By pumping until the air escaped out of the funnel, which would then bubble up through the water in the cistern, an even and constant pressure could be maintained. The pressure would be as the water displaced, measurable exactly as with the syphon water-gauge, by the difference in levels of the water. Seeing that the average hand-blown organ now has a wind pressure of $3\frac{1}{2}$ ins. on the gauge, and such displacement would mean very little storage with the hydraulus, it is possible wind pressures on this instrument would most likely have been upwards of 15 ins. The compensation being the small quantity necessary for few pipes, this would be practical by means of the lever pumps. It seems the ancients liked their flute pipes to sound like hooters.

7. In Roman times the hydraulus was a developed instrument with stops and a keyboard, its origin dating from 300 to 246 B.C., and ascribed to the invention of Ctesibius, an Egyptian mechanician, who lived in the time of Ptolemy Eurgetes I, whose predecessor, Philadelphus, it is recorded, greatly encouraged the art of music. Philon, the Byzantine mechanician, refers to Ctesibius, describing the hydraulus as a kind of "syrinx played by the hands, and that kind of bellows by which the pnigeus or air condenser was filled with air was made of copper."

8. It would seem from the distinction made between the air condenser (reservoir) and the copper air pumps, the latter only were novel. If this could be asserted, then the syphon reservoir was of even more ancient origin. Seeing the water-organ of Ctesibius had a keyboard (about 300 B.C.), and that, when introduced into the Church about the

fifth century the organ was stripped of keys and stops back again to a primitive form, and that keys of a sort only began again in the eleventh century, it is unlikely that the water-organ of 300 B.C. was the original, complete with scientific blowing and keys, without allowing for a previous development.

It is said the system of blowing of the hydraulus survived, with modifications, to the tenth century. In the eleventh century some organ builder introduced the "pallet" under the pipes, discarding the playing slide of antiquity. Lower wind pressure became essential, and the forge bellows returned to favour.

9. We conjecture, for very practical reasons, the forge bellows of the mediæval organ, exterior, was connected to another of the same inside the instrument, the "feeder" and bellows being separated, after the manner of the sketch 29, Block F.

10. The next step combined them within the organ, originating the "diagonal" bellows and feeder, diagram 30. The origin of the "rising" frame is illustrated, 31, as the combination of two hinged bellows, one upon the other. The next step discarded the hinge, and the bellows lifted parallel. The sketch 32 completes the parallel bellows, with rising frame, and double folds. Some old bellows had two rising frames, with treble folds. We know of one still extant. At the Renaissance the storage capacity had become so great that the lower part of the case was filled.

11. So far none of these improvements from the time the hydraulus was scrapped made the wind as constant as before, until the invention of the inverted ribs. This was wont to appear as a great feature in the details of construction as a "double rise bellows with inverted folds," and has already received notice in the section dealing with bellows. For the purpose of adding to that section, and bringing the subject up to the time of writing, we continue.

12. Hand Blowing. Hand blowing is usually by means of a lever. A more complicated method was an eccentric shaft with three hinged feeders, revolved by a handle on a heavy fly-wheel. An older

method is a very skilled piece of engineering with a three-point eccentric forged without a shaft, the feeders being one above the other.

13. The single feeder and lever answers very well for small organs, as the sketch, 30. The more usual method is by a lever extending the length of the bellows, centred upon a fulcrum, with connecting rods down to two feeders upon the underside of the bellows, arranged to balance each other. A further development added to this a counter-lever which picked up the other, as at 32 (Block F). One feeder can be larger than the other to use the weight of the blower on the downstroke, and lighten the upstroke. A large three-manual tracker organ can be blown easily in this way, providing pressure is about 3 ins. The limit for "man-power" is 3½ ins. pressure on a two-manual. Add automatic action to this, and power is necessary. With any but quite a small organ it is essential for the organist to keep the blower constantly in mind to avoid working him too hard. No one regrets the days of hand-blowing are numbered. Of recent years, owing to the increase of pressure, the blower's job has not only become more laborious, but it is the rule to limit the number of levers to one so that only a single blower can find room. One we knew had a method of dealing with visiting organists who exceeded his limit, by jerking the trace-rods off the feeders, which were suspended in "stirrups," so the organ was out of gear until the organ builder came. Another insisted upon removing the bellows-weights, "to make it blow easier," as he said. It seems not inappropriate to mention the electrician who did the same to suit the peculiarities of his blowing machinery, hiding the weights in the stroke-hole. And the boy, who, asked to "Go behind and blow," did so according to his notion by vigorously distending his cheeks with the effort.

14. General Arrangement. Originally the method was one huge bellows for the whole organ. This developed by adding small reservoirs close to the soundboards. T. C. Lewis used this method with all but small organs, connecting to the soundboard by a concertina trunk which folded up as the reservoir lifted.

15. The theory was to eliminate long wind-trunks, and as the reservoirs were supplied from the heavy wind, the main bellows took all the jolts. It follows when the light wind reservoirs are trunked from the heavy, easing the pressure down by stages, that the main bellows moves most when demands are made, so the pipe-wind is kept steady. This method has been illustrated previously. From being used first to work the automatic action, pressure was turned to account for reeds.

16. Power Blowing. Power was introduced mainly on account of the automatic action, which called for an increase of volume and pressure. The earliest method was the hydraulic engine, which is a cylinder with plunger, water under pressure from the main entering alternately by a port top and bottom. Some engines worked one way only, the feeder reversing by its own weight. Rotary water engines finally developed with two and three cylinders. The control was a valve opened and closed in connection with the bellows' top. Some engines were simply connected to the blowing lever. A more elaborate arrangement for two vertical engines is illustrated previously herein. The cost of water power varies greatly. Obviously, the higher the pressure in the power main the less the volume of water required. The organ illustrated herein (three-manual) affords an extreme instance where water power is dear and electricity cheap. Before the change was made, the cost of water was sixteen to eighteen pounds annually, whereas now, with a centrifugal single stage fan, the charge is one pound annually. In the north of Britain it was possible to blow a small organ by water power for thirty shillings per annum.

17. At the present it is hardly worth while considering any means but electricity.

18. Electric Power. When introduced the current was what is now termed "direct." Motors adapted to this are governed by brush contacts and the speed of the rotor can be varied to suit the demand on the organ wind. These motors are the most expensive to make.

19. One of the earliest applications to organ blowing outside London, where three or four were in use at the time, was at St. Paul's Church, Princes Park, Liverpool. A motor of German manufacture was used as being the quietest then, placed behind the organ. It revolved a crank-shaft by means of a belt and pulley, and so worked three feeders. Speed was varied by wire resistances.

20. The electric motor is really only efficient at speed, which is not required by feeders. An improvement on the foregoing was the reducing gear in direct connection to the motor and eccentric, the most silent being the screw drive and helical-cut gear immersed in oil. Even so, resistances are necessary. A further advance was made by introducing what is now known as a "dimmer" into circuit. This is an earthenware pot filled with water through which an electrode is lowered by connection to the bellows: as this drops resistance decreases, and the motor speed increases. It is regulated by acidulating the water

21. A constant supply of water can be maintained to counter evaporation by a jar and syphon which automatically keep up the level.

22. This method of blowing is illustrated on Plate 7. No improvements have been made since we mentioned it. It is very quiet and efficient, but more expensive than hydraulic plant to make, and running cost is high, as most current goes in resistance.

23. Alternating Current. This being cheaper to produce, as it simplifies the power station, and transmits with less loss, it has almost ousted direct current. There are, however, a few purposes which demand direct current—as lifts and some printing machines.

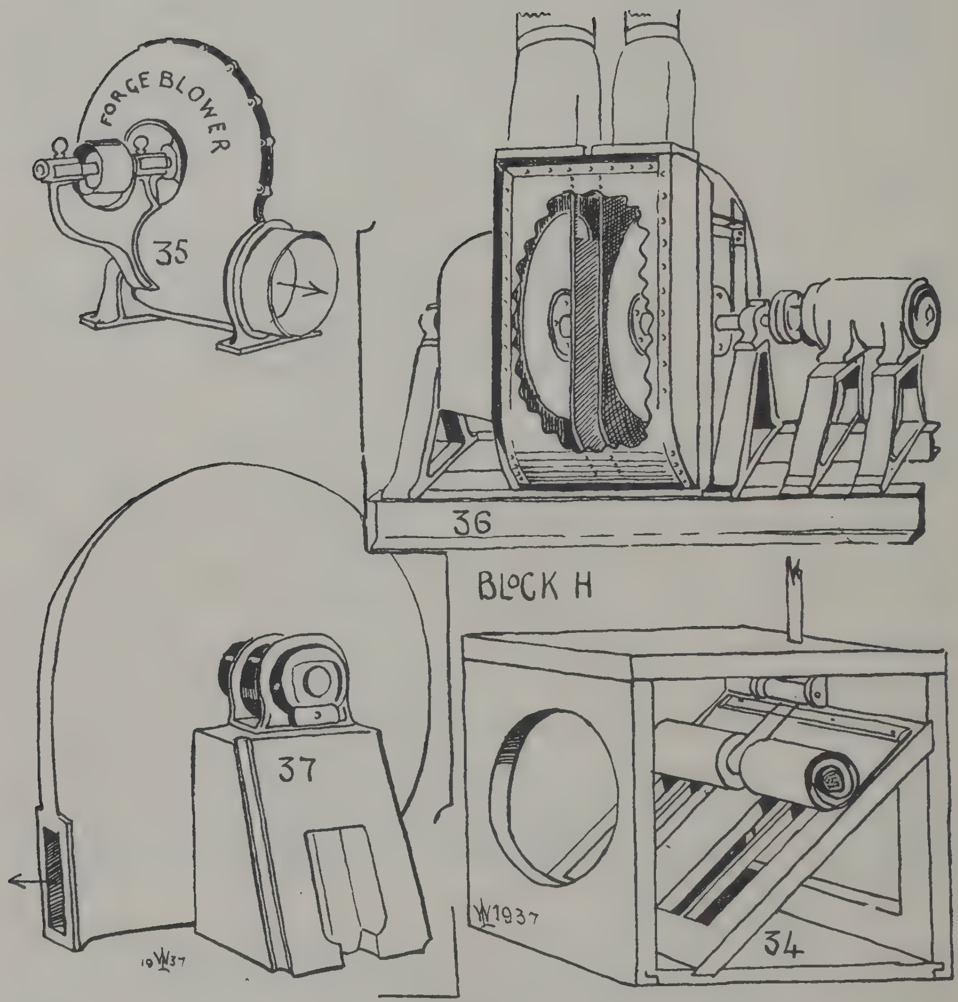
24. The characteristic of an A.C. motor is that its speed cannot be varied by resistance. Special motors can be made to give several speeds, but such are not practical for organ blowing. The introduction of this current started another chapter in the trade. The history of A.C. blowing shows a continual adaptation to the motor, whereas the motor was originally adapted to the organ.

25. The first attempt to use A.C. for organ blowing was made at Bedford Church, when Dr. Harding, then President of the R.C.O.,

was organist. The method followed was that used with D.C., as described, but as speed could not be controlled, a fast and loose pulley and a belt drive were used, and the strap thrown off and on by mechanical means from the bellows. This proved too noisy, and the plant was removed in favour of hydraulic, as the conclusion was a transformer and D.C. motor, the cost of transforming being about a pound a week.

26. Nevertheless, a large number of A.C. motors have been used in conjunction with feeders. The alternative to letting the plant run at a geared down speed to suit full organ, allowing surplus to waste, or return into the feeders by safety valves (as previously described)—which is for the greater part of the time—is, in addition to the machinery necessary for D.C. drive, a fast and loose pulley for the strap to throw off and on, with automatic gear to do this, which can be pneumatic. This method is costly to make and maintain, is not self-starting, and is noisy. It sums up all a plant should not be. Hence when we wrote before on this subject, we gave preference to hydraulic power, as recorded in an earlier chapter. Nor was a really efficient centrifugal blower much advantage at that time, as the multiple stage blower could be too ponderous, expensive and noisy, sometimes not self-starting, and really needed an engineer to look to the bearings. It was sometimes the opposite of the teaching of the trade, as all organ mechanism was designed to be quiet, and to be efficient without constant attention.

27. The Rotary Blower. There is no better method of seeing all round the subject than the historical one, accordingly we must again refer to Robert Hope Jones, who started rotary fan blowing by putting a forge blower to the organ at St. Cuthbert's, Edinburgh. It was placed in the tower upon a pile of mats, but even so was too obvious, although it served its purpose for years. The type of forge blower used is sketched, 35, Block H. It was on the small side speeded above the motor revolutions by a belt. The impellors of the



Block H

FORGE BLOWER, 35. MULTIPLE STAGE BLOWER, 36. SINGLE STAGE DIRECT COUPLED CENTRIFUGAL FAN BLOWER, 37. ROLLER VALVE, 34

fan exerted a drive against the air in the case, throwing it towards the outlet.

28. The fan is used as it is adapted to the most efficient way of using the invariable and comparatively high speed of the A.C. motor, of which there are two principal kinds—one designed for three-phase, the other for single phase. The former is best for organ blowing, but unfortunately is not always available.

29. Following Hope Jones, the most remarkable consequence was the multiple stage blower, invented by Messrs. Cousins, the organ builders of Lincoln, which scrapped all previous theory. Messrs. Cousins used a slow running motor coupled to a shaft upon which several fans were bolted, connected in series. The fan was a disc with small impellors fixed to it, and the several fans were so enclosed that the intake of one was connected to the outlet of the other, so the wind was passed through the series getting a lift in pressure from each one. This invention decided the future of fan blowing at the time, up to a decade or so ago.

30. The first forge blowers were rotary fans, the first multiple blowers being a step in the direction of the centrifugal fan, which now holds the field. Although wind off the centrifugal fan exerts a drive in the direction of rotation of some consequence, providing the case is curved to advantage from it, the principal impetus is derived from the centrifugal effect of the impellors. The fan is designed to throw air from the intake at the centre to the circumference.

31. A multiple stage blower of steel sheet with a steel girder bed and cast standards and ball bearings is illustrated, 36, Block H, with a portion of the case removed to show part of a fan with an intermediate compartment for receiving a supply to pass on to the next. So the practice was commended by engineers of tapping off supplies at different stages of pressure (instead of trunking the organ through reservoirs, all from the main, indirectly), as indicated on the sketch, which shows two flexible connecting links to the organ trunks.

32. The very general formula of the fan is, that volume of wind

is, practically, as the speed, whilst pressure increases as the square of the revolutions, the H.P. being as the cube of the revolutions. But as the result works out from the efficiency of any given type of fan, the design is of first importance, being mainly derived from experience.

33. The principal objection to the centrifugal, as differing from the fan or part fan part centrifugal impetus, was that the marked increase of efficiency was offset by noise. It seems the revolution which appears likely to end in making the multiple stage blower unnecessary, very exceptional circumstances omitted, was introduced from the Continent. Now it is possible to design a single fan that will give any volume up to, say, 10 ins. pressure, in conjunction with a slow running motor of very moderate power, and yet be more silent than any type of multiple stage blower.

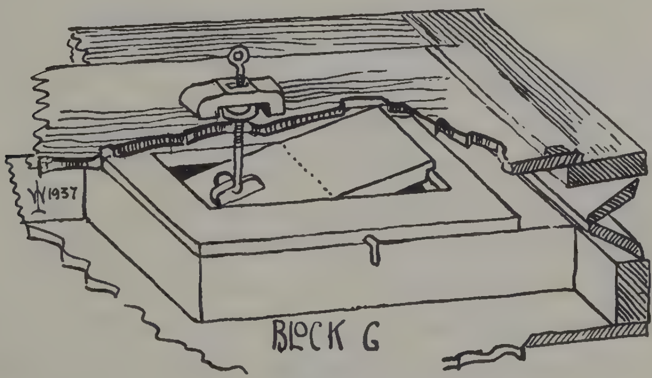
34. This method cuts out all intermediate gear by bolting the fan direct on to the motor. The single stage blower, as this method is called, is illustrated 37, Block H. In making comparisons it must be remembered that, with any fan whatever, the greater the output (volume and pressure combined) the less silent it will be. This is true, we believe, of any machine, that the noise it makes increases as power is developed.

35. The single stage blower has been carried further towards simplification by using high speeds. This, however, must have decided limitations, and is also in the direction of noise, which must be suppressed by enclosing the motor It seems to us preferable to select a method which does not create more noise, but if possible, less. No amount of trouble can make a noisy machine quiet if the trouble is inherent. The domestic vacuum cleaner is an example of a high speed motor and very small fan, the intention being to make it as portable as possible. No organ-blowing fan is *absolutely* silent—it is a question of degree.

36. Position. The position of the blower is usually decided by circumstances, and often admits no choice. A great point is some

times made with small machines of putting them inside or adjacent to the organ. This means they must be enclosed. Considering that 50 ft. of connecting pipe (merely for example) causes a frictional loss of but $\frac{1}{4}$ to $\frac{3}{8}$ in. pressure with pipes of the usual range of diameters, this is negligible. Inside the organ the machine is less accessible, or else it may make access to the instrument difficult. It is best to consult the organ builder.

37. Wind Control Valves. An essential part of any automatic blower is a control valve, and some of the quietness and efficiency of the plant depends upon it. The types used were all developed in organ building before the rotary fan was used in this connection. On Plate 10 is illustrated one kind, the equilibrium, or balanced type. When originally designed for automatic blowing, the valve is generally provided inside the bellows, as illustrated on Block G. The sketch shows a corner of a single rise bellows with a



Block G

BALANCED WIND CONTROL VALVE IN RESERVOIR

simpler form of balanced valve which closes as the bellows lifts, so automatically cutting off the supply from the blower, which of course comes from the underside. It is a flat piece of wood which tilts on a centre, so pressure on one side neutralises that on the other, and there is no pull on the top of the bellows.

38. On Plate H, 34, is sketched a roller valve (or curtain valve) shown arranged in a box apart from the bellows, to which it may be fixed. As sketched the side nearest is removed to show the arrangement of the roller, which unrolls the leather valve over a grid by means of a tape passed through a slot to the exterior for connection to the bellows top. All control valves connect in some way to the top of the bellows. On the example the supply comes through the circular hole. A still older form is the slide valve—a flat piece of wood which is drawn over the supply hole as the bellows lifts.

39. Some are puzzled to account for the wind generated by a blower when the valve shuts, or nearly shuts, which happens when the organ is not being played and the fan, of course, rotates at exactly the same speed as for full organ. The explanation is, that whatever the maximum output of pressure may be from any given fan, it cannot exceed it even with the outlet closed. Regarding volume, the more the control valve opens, the more passes through the machine to replace it. It is now possible to design a fan that will automatically compensate the drop in pressure that, on the old theory, must follow from drawing upon the volume.

40. Modern Developments. As the wind from the rotary blower is constant, and is always behind the valve waiting for admittance to the organ, the necessity for much storage capacity has ceased to operate. For this reason reservoirs are smaller than formerly. Further, the right combination of fan, reservoir and valves, admits of the single rise reservoir, with springs. The theory is that as weights have inertia, they do not exert the same force when the bellows drops quickly—in response to a sudden demand—as when it is stationary. Springs have no inertia.

41. A prompt response to full staccato chords, for instance, is not entirely dependent upon the action, but also upon the wind supply, and several other factors. So the double rise bellows with inverted folds appears likely to be simplified to the single rise. The extreme theory in this direction is illustrated by the diagram 33,

Block F. In essentials this is a bellows and control valve without storage capacity. It is hinged and opens against springs the resistance of which increases as the bellows lifts. An ordinary pallet is pulled shut as the bellows lifts. The supply from the blower comes from the direction of the pointer on the sketch, passes through the pallet, and goes on to the soundboard. When any demand is made upon the wind, the pressure in the bellows drops, and it collapses to that extent automatically, so opening the pallet, and renewing its supply.

42. The theory is based upon the complementary phases of the wind supply, which manifests as pressure and volume respectively. *Pressure* is static—wind in motion loses pressure but acquires an equivalent, namely, *velocity*, therefore energy remains constant (minus frictional loss, however). So pressure is the static equivalent of velocity, and velocity the kinetic equivalent of pressure. The origin of this method was the little governor bellows of the player machine which, arranged on the supply to the motors rotating the roll-music, assisted in maintaining the *tempo* constant.

43. By this means the reservoir, and storage capacity of the bellows, is made unnecessary. Further, by providing one for each stop, various pressures may be adjusted by the springs (less than the supply) to differ from each other, if required, in conjunction with the pneumatic soundboard, which uses a ventil for each stop, as explained herein.

44. Here then, we conclude, and fearing we may have criticised for the guidance of the reader enough—not, however, for any benefit to ourselves—we leave him with freedom to form his own conclusions respecting the all-important matter of the organ wind supply, as to whether the older method of connecting the light wind through the heavy is best, as illustrated in Chapter III; or by tapping off supplies from the stage blower direct; or by eliminating all wind trunks and combining bellows and sound-board, or the whole organ in a universal chest; or (the opposite) the elimination of reservoirs and bellows in

favour of the automatic valve of the simplest, as last explained; with connecting trunks.

45. The following table may be useful in arriving at equivalence between round pipes (or valves) and square or rectangular wood trunks (or valves).

Diameter of Pipe Inches	Area Square Inches	Sides of Square same Area Square Inches
3	7.069	2.66
3½	9.621	3.10
4	12.566	3.54
4½	15.904	3.99
5	19.635	4.43
5½	23.758	4.87
6	28.274	5.32
6½	33.183	5.76
7	38.485	6.20
7½	44.179	6.65
8	50.266	7.09
8½	56.745	7.53
9	63.617	7.98
9½	70.882	8.42
10	78.540	8.86

46. The following illustrates the relation between velocity and pressure as read in inches on water gauge, within usual limits.

Gauge	Pressure Square Foot (or Weight, or Springs)	Velocity Miles per Hour
3 ins. . . .	15 lbs. 9 ozs. . . .	56.29
6 ins. . . .	31 lbs. 3 ozs. . . .	79.61
9 ins. . . .	46 lbs. 12 ozs. . . .	97.5

INDEX